

EXAMINATION OF EXPERIENCED CHEMISTRY TEACHERS'
PEDAGOGICAL CONTENT KNOWLEDGE ON SOLUTION TOPIC

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ABSTRACT

EXAMINATION OF EXPERIENCED CHEMISTRY TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE ON SOLUTION TOPIC

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Shulman (1986) stated that the main difference between a teacher and an expert in that field is pedagogical content knowledge. Shulman's work has become a new research topic in the field of education and many researchers have presented models related to the subject (Magnusson, Krajcik, & Borko, 1999; Abell, 2008). Due to the subject-specific nature of pedagogical content knowledge, teachers' pedagogical content knowledge should be examined within the scope of the subject. In this study, the pedagogical content knowledge of experienced chemistry teachers on solutions was examined. In line with the purpose of the study, experienced chemistry teachers' knowledge of solutions, knowledge of educational strategies, curriculum knowledge and assessment knowledge were investigated. All pedagogical content knowledge components were examined in order to analyze the structure of the participants' pedagogical content knowledge. The study was carried out with 3 chemistry teachers working in high schools affiliated to the Ministry of National Education. While selecting the participants, it was taken into consideration that they had at least 5 years of experience, had worked in different schools, were open to cooperation and would respond sincerely. In-class observation, semi-structured interview, CoRe and card

grouping activities were used as data collection tools in the study. Constants comparative data analysis method was used to analyze the data. The results of the study revealed that the pedagogical content knowledge of the teacher is effective on the teacher's instructional strategies. In addition, it was revealed that the physical facilities of the schools, the curriculum and student characteristics (readiness level, success level, etc.) have an effect on pedagogical content knowledge. We may conclude that teachers' pedagogical content knowledge is dynamic construct and it is shaped by contextual factors.

Keywords: Pedagogical Content Knowledge, Chemistry Teacher, Solutions

ÖZ

DENEYİMLİ KİMYA ÖĞRETMENLERİNİN ÇÖZELTİLER KONUSUNDAKİ PEDAGOJİK ALAN BİLGİLERİNİN İNCELENMESİ

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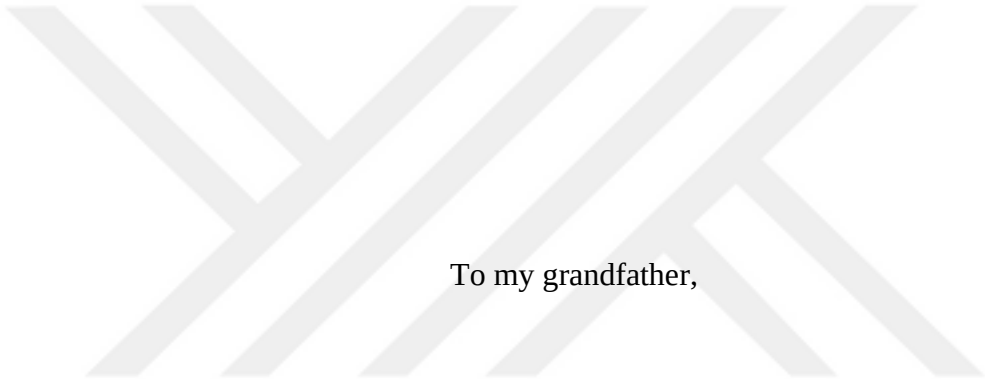
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Shulman (1986) alan öğretmeni ile o alan uzmanı arasındaki temel farkın pedagojik alan bilgisi olduğunu ifade etmiştir. Shulman'ın çalışmaları eğitim alanında yeni bir araştırma konusu olmuş ve pek çok araştırmacı konu ile ilgili modeller ortaya koymuştur (Magnusson, Krajcik, & Borko, 1999; Abell, 2008). Pedagojik alan bilginin konuya özgü doğası gereği öğretmenlerin pedagojik alan bilgileri konu kapsamında incelenmelidir. Bu çalışmada deneyimli kimya öğretmenlerinin çözeltiler konusundaki pedagojik alan bilgileri incelenmiştir. Çalışmanın amacı doğrultusunda deneyimli kimya öğretmenlerinin çözeltiler konusundaki öğrenci bilgisi, eğitim stratejileri bilgisi, müfredat bilgisi ve değerlendirme bilgisi araştırılmıştır. Katılımcıların pedagojik alan bilgilerinin yapısını analiz edebilmek için bütün pedagojik alan bilgisi bileşenleri incelenmiştir. Çalışma Milli Eğitim Bakanlığı'na bağlı liselerde görev yapan 3 kimya öğretmeni ile yürütülmüştür. Katılımcılar seçilirken en az 5 yıl deneyimli olmaları, farklı okullarda görev yapmış olmaları, işbirliğine açık olmaları ve samimi cevap verecek olmaları göz önünde bulundurulmuştur. Çalışmada veri toplama aracı olarak sınıf içi gözlem, yarı yapılandırılmış mülakat, CoRe ve kart gruplama aktivitesi kullanılmıştır. Verilerin incelenmesi için sürekli karşılaştırmalı veri analiz yöntemi kullanılmıştır.

Çalışmanın sonuçları öğretmenlerin sahip olduğu pedagojik alan bilgisinin öğretmenlerin öğretim stratejileri üzerinde etkili olduğunu ortaya çıkarmıştır. Bunu yanı sıra okulların fiziki imkanlarının, müfredatın ve öğrenci özelliklerinin (hazır bulunuşluk düzeyi, başarı düzeyi vb.) pedagojik alan bilgisi üzerinde etkisi olduğu açığa çıkmıştır. Çalışmanın sonuçları göz önüne alındığında pedagojik alan bilgisinin dinamik bir yapıda olduğu ve bağlamsal faktörlerden etkilendiği sonucuna varılabilir.

Anahtar Kelimeler: Pedagojik Alan Bilgisi, Kimya Öğretmeni, Çözeltiler





To my grandfather,

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CHAPTER 1

INTRODUCTION

In order to increase the quality of education, it is necessary to train teachers who are aware of the changing needs of their students and can respond to these needs appropriately (Magnusson, Krajcik, & Borko, 1999). Teacher is one of the most important factors on teaching process (Van Driel, Beijaard, & Verloop, 2001). Skills of teachers effects the quality of teaching and Pedagogical Content Knowledge (PCK) is one of the important skills (Van Driel, De Jong & Verloop, 2001). PCK was proposed by Shulman (1986) as “amalgam” of content knowledge and pedagogical knowledge in order to improve students’ learning. Shulman also stated the major difference, in terms of knowledge between content specialist and teacher as PCK. Shulman’s study has opened a new era in educational research as teacher knowledge and many models were proposed by researchers (Magnusson, et al., 1999; Abell, 2008).

PCK was defined by Shulman (1987) as ‘the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adopted to the diverse interests and abilities of learners, and presented for instruction’. Content knowledge is necessary but not sufficient alone for a teacher (Kind, 2009). For effective education, teachers should not only define knowledge within a field to their students but also be able to assess the readiness of the learners. Teacher should bridge two gaps; the divide between isolated knowledge and the student as an individual, and the gap between specialized knowledge and social progress (Wahlström, 2022).

Subject matter knowledge (SMK) is robust in a particular topic, it can aid in understanding prerequisite knowledge, potential difficulties, and misconceptions. As

suggested by Shulman (1986), Grossmann (1990), and Magnusson et al. (1999), PCK is formed through the transformation of SMK into a form understandable for learners. Teacher should know how knowledge in a particular field needs to be taught, explain why that knowledge needs to be learned, and illustrate its connections with subjects within the same or different disciplines (Shulman, 1986). This issue addresses the main difference between content specialist and teacher. For this reason PCK is a specific theme for education. Similar to content specialist, teacher should have solid content knowledge but teacher should also know how to organize and transfer the knowledge regarding student needs (Morrison & Luttenegger, 2015).

From the 1980s onward, the focus of studies in teacher education shifted from the behaviors of teachers to a more profound transformation regarding the knowledge and beliefs held by teachers. Pedagogical knowledge and content knowledge were particularly popular research topics for teacher education. Although concepts related to the knowledge that distinguishes teachers from content specialists have been mentioned in previous teacher education studies, the term PCK, which reflects a specialized type of knowledge for teaching a subject area, was first used by Shulman (1986). Shulman (1986) pointed out that teacher knowledge can fundamentally be categorized into three main groups. Shulman classified this knowledge as content knowledge, pedagogical content knowledge, and knowledge of the curriculum. Content knowledge was defined as the quantity of knowledge in a teacher's mind and its organization, requiring an understanding of concepts and facts within a specific field. Knowledge related to the curriculum, on the other hand, refers to information encompassing programs designed to teach specific subjects at a certain level, including materials aligned with these programs.

1.1 Significance of the Study

The concept of pedagogical content knowledge has been widely used in the educational literature. Shulman (1986) suggests that 'science teachers, to meet the high goals that they and others set for them, would need to develop more professional

and pedagogical knowledge, which are specialized epistemological constructs. The specialty of knowledge is not a matter of simply having more of it; it is, rather, an appreciation of knowledge's uniqueness and its importance. Grossman (1990) stated PCK as an important indicator of teachers' classroom practice. Kind (2016) mentioned the importance of PCK on teachers' actions and decisions in the learning environment. PCK is crucial for curriculum development, teacher training, and improving student learning outcomes in science. Outputs of PCK studies may help educational stakeholders to create more inclusive and effective science education environments that meet the needs of all learners. valuable insights into the diverse ways teachers approach chemistry instruction and the factors influencing their pedagogical decisions

Investigating teachers' PCK in a specific subject area yields valuable insights for the literature. Moreover, PCK not only subject specific construct but also topic specific construct. Each topic is unique and PCK researches are conducted on topics, rather than subjects. Researchers, in the field of chemistry education, study in various topics such as; particulate nature of matter (Canbazoglu, Demirelli, & Kavak, 2010), electrochemistry (Aydin, 2012;), radioactivity (Aydin, Friedrichsen, Boz, & Hanuscin, 2014), mixtures (Kıran, 2016). Result of these studies gives valuable information about PCK, but each chemistry topic should be studied separately. This study is designed to analyze PCK on solutions topic. Findings could serve as a basis for comparison with PCK studies on other chemistry topics, contributing to a more comprehensive understanding of chemistry PCK.

When the studies conducted in our country in the field of PCK in science teaching were examined, it was seen that the majority of the studies were conducted with pre-service teachers and that the number of studies conducted with experienced teachers was few (Öztürk Ferah, H, 2022; Aydın, 2012; Canbazoglu, 2008; Uşak, 2009). Aydın & Boz (2012) advised to study PCK with experienced teachers because pre-service teachers may not have robust PCK. For this reason, this study was conducted with experienced chemistry teachers.

This study could give valuable insights into the diverse ways teachers approach chemistry instruction and the factors influencing their pedagogical decisions. Output of this study could be valuable in terms of teacher education and professional development. Findings could inform the design of more effective pre-service teacher education programs, emphasizing the development of topic-specific PCK. Also, findings may guide the creation of targeted professional development programs for in-service teachers to enhance their PCK on solutions. In terms of curriculum design, this study give insights into experienced teachers' PCK could influence how the topic of solutions is presented in chemistry curricula.

1.2 Purpose of the Study

Purpose of this study is to investigate experienced chemistry teachers' pedagogical content knowledge on solutions subject. Experienced chemistry teachers' knowledge of learner, knowledge of instructional strategy, knowledge of curriculum and knowledge of assessment for teaching Solutions topics are investigated in this study.

1.3 Definition of Important Terms

Shulman (1986) defined Pedagogical Content Knowledge (PCK) as “the ways of representing and formulating the subject that make it comprehensible to others”. In this study PCK was studied by semi-structured interviews, card-sorting activity and content representation (CoRe).

According to Friedrichsen et. al. (2011), science teaching orientation is "complex set of beliefs and values that influence how a teacher teaches science, including the goals of science instruction, the nature of science, and science teaching and learning."

"Knowledge of curriculum" is another key component. This component refers to a teacher's understanding of the goals, content, and organization of the science curriculum for teaching science

“Knowledge of instructional strategies”, a PCK component, refers to a teacher's understanding of the various teaching approaches, methods, and techniques that can be used to effectively facilitate student learning in science. Magnusson et. al. (1999) emphasizes that knowledge of instructional strategies is not a fixed set of techniques but rather a dynamic and evolving aspect of PCK. Teachers refine this knowledge through continuous professional learning, experimentation, and reflection on their teaching practice.

According to Magnusson et. al. (1999) model of PCK for science teaching, "knowledge of students" is one of the five key components of PCK. This component refers to a teacher's understanding of students' prior knowledge, misconceptions and learning difficulties in relation to specific science topics.

"Knowledge of assessment" refers to a teacher's understanding of the various methods and tools that can be used to evaluate student learning and progress in science (Magnusson et. al., 1999). This component includes knowledge of both formative and summative assessment strategies and how to use assessment data to inform instruction. Magnusson et. al. (1999) emphasizes that knowledge of assessment is not a separate or isolated aspect of PCK but rather is closely interconnected with the other components.

CHAPTER 2

LITERATURE REVIEW

2.1 PCK Models

Starting from the shift in focus from teachers' behaviors to their knowledge and beliefs in the mid-1980s, scholars have delved deep into understanding how teachers develop the unique amalgam of content and pedagogy essential for effective teaching. Shulman's groundbreaking work in the 1980s laid the foundation for conceptualizing PCK. His idea of PCK as the special amalgam of content and pedagogy unique to teachers sparked a paradigm shift in teacher education research. Shulman identified three basic categories of teachers' knowledge: subject matter content knowledge, pedagogical content knowledge, and curricular knowledge. Later, he expanded this to include general pedagogical knowledge, knowledge of learners, knowledge of educational context, and knowledge of educational ends, purposes, and values.

Various scholars built upon Shulman's work, offering different models and perspectives on PCK. Some highlighted the importance of subject-specific knowledge, while others integrated different knowledge components into comprehensive frameworks. For example, Tamir (1988) emphasized subject matter specific pedagogical knowledge, while Grossman (1999) proposed a model with four main components: subject matter knowledge, general pedagogical knowledge, knowledge of context, and pedagogical content knowledge.

Tamir (1988) examined the types of knowledge possessed by teachers from the perspective of knowledge and skill components, subdividing them into the categories of content knowledge, general pedagogy, and subject-specific pedagogy. The content knowledge encompasses understanding the fundamental ideas and theories within a discipline and possessing skills related to that field. General pedagogy and subject-specific pedagogy, on the other hand, consist of components such as students, curriculum, education (teaching and management), and assessment. Unlike Shulman's PCK model, Tamir (1988) also added an assessment dimension to PCK. Grossman (1990) proposed a new model for teachers' professional knowledge by making additions to Shulman's model. In Grossman's model, teacher knowledge is defined across four fundamental domains: content knowledge, general pedagogical knowledge, pedagogical content knowledge (PCK), and knowledge of context. These domains encompass the areas of expertise that form the basis of a teacher's professional knowledge.

In another model proposed for PCK, Marks (1990) suggested that PCK comprises primarily four main domains. These domains are defined as subject matter for teaching purposes, understandings of the students related to the subject, tools for teaching the subject (such as texts and materials), and instructional strategies related to the subject. Marks highlighted that these domains are highly interconnected. He also mentioned the difficulty in determining where one set of knowledge begins and another ends within PCK due to its derivation from different types of knowledge.

Cochran, King, and DeRuiter (1991) identified PCK as a distinctive form of knowledge for teachers, arising from the synthesis or integration of pedagogical knowledge and subject matter knowledge. They mentioned that PCK emerges when a teacher combines their knowledge about what they are teaching with what they know about teaching itself. Rather than using the term pedagogical content knowledge, they preferred the concept of Pedagogical Content Knowing (PCKg) to emphasize that this knowledge is not static but dynamic. They highlighted the centrality of understanding Pedagogical Content Knowing as an intersection and

interaction of pedagogy, subject matter, student, and educational contexts, shaping and being shaped by them.

Carlsen (1999) classified teacher knowledge into five general domains: knowledge about the general educational context, knowledge about the specific educational context, general pedagogical knowledge, subject matter knowledge, and PCK. In this classification, PCK is structurally distinguished from other elements of teacher knowledge and is defined as a distinct entity, albeit related to general pedagogical knowledge and subject matter knowledge. Additionally, students' common misconceptions, a specific science curriculum, subject-specific instructional strategies, and goals related to science education constitute the categories of PCK.

Gess Newsome (1999) proposed two models as integrative model and transformative model. In the integrative model, PCK doesn't exist as a separate knowledge domain. In this model, teachers combine subject matter knowledge, pedagogical knowledge, and contextual knowledge to conduct teaching, aiming to create effective learning opportunities. In the transformative model, PCK emerges from the synthesis of subject matter knowledge, pedagogical knowledge, and contextual knowledge. Within this model, PCK is the only knowledge used by teachers during instruction to help students understand a specific concept. Merely possessing subject matter knowledge, pedagogical knowledge, and contextual knowledge isn't sufficient in the transformative model; these pieces of information need to transform into PCK to be useful.

Loughran, Berry & Mulhall (2006) defined PCK as the knowledge that teachers develop over time through their experiences. This knowledge is about how they teach specific content in specific ways to enhance student understanding. They also mentioned that this structure can be influenced by context, experience, and content, and that teachers may exhibit similar, comparable, or different characteristics regarding this knowledge.

Magnusson, Krajcik, & Borko, 1999) proposed a model explaining PCK for science education with five components; orientation toward science teaching, knowledge of

curriculum, knowledge of instructional strategies, knowledge of students, knowledge of assessment. Magnusson et al.'s (1999) model illustrating the components of PCK also highlights the elements that should be present in teacher education programs. These elements include being aware of the goals of science education and the teaching strategies aligned with these goals, planning and implementing instruction while considering student understanding, and conducting assessments that align with the intended objectives and goals.

2.1.1 Consensus Model

A summit on PCK in 2012, a model of professional expertise encompassing PCK was proposed, which later came to be known as the Consensus Model (Gess-Newsome, 2015). Consensus Model aims to provide a clearer and more unified understanding of the complex nature of PCK, which integrates both content knowledge and pedagogical knowledge essential for effective teaching. This model offers a potentially powerful framework for understanding the relationships among teachers' various professional knowledge bases. Consensus model has mainly five components as; subject matter knowledge, knowledge of students, knowledge of instructional strategies, knowledge of curriculum, knowledge of assessment. This model also emphasizes the importance of personal characteristics and context as amplifier and filters.

This model represents an attempt to synthesize different perspectives on PCK and provide a more coherent framework for understanding and researching this construct. Key features of the consensus model include:

- **Teacher Professional Knowledge Bases:** These include knowledge of assessment, pedagogy, content, students, and curriculum.
- **Topic-Specific Professional Knowledge:** This is knowledge specific to teaching particular topics, including instructional strategies, content

representations, student understandings, science practices, and habits of mind.

- •Classroom Practice: This includes personal PCK and skill, which is the knowledge and enactment of teaching specific topics in specific ways.
- •Amplifiers and Filters: These include teacher beliefs, orientations, prior knowledge, and context, which influence how teachers translate their knowledge into practice.
- •Student Outcomes: The model explicitly includes student outcomes, recognizing that the ultimate goal of PCK is to improve student learning.
- •Feedback Loops: The model includes arrows indicating that classroom practice and student outcomes can inform and refine a teacher's professional knowledge bases and topic-specific professional knowledge.
- •Distinction between Personal and Canonical PCK: The model recognizes both the personal nature of PCK developed by individual teachers and the collective or canonical PCK shared within the profession.

This consensus model attempts to address some of the complexities and debates in PCK research, such as the relationship between general and topic-specific knowledge, the role of teacher beliefs, and the connection between PCK and student outcomes. It provides a framework for future research and discussions about PCK in science education.

This model emphasizes the dynamic nature of PCK and PCK is stated as ever-evolving construct. In-service training programs, interaction with colleagues and classroom teaching experience are seen as source for PCK development. Besides consensus model recognizes the dynamic nature of PCK. This issue explained as enactment of PCK, which mentions the effect of instructional practices and interaction with students on PCK development.

This model also highlights the complexity of PCK. The model acknowledges the multifaceted nature of PCK, including its topic-specific aspects and the various factors that influence its development and application.

The model serves as a guide for developing teacher education programs and professional development initiatives. It highlights the specific knowledge and skills that teachers need to develop to be effective in their practice. This model also provides a structured framework for studying the complexities of teaching and learning. Researchers can use it to investigate how different types of knowledge interact and contribute to effective teaching. Curriculum developers can use the model to create instructional materials and resources that are aligned with in the model, by the way curriculum could be not only rich in content but also pedagogically sound.

2.1.2 Re-defined Consensus Model

The Refined Consensus Model (RCM) of PCK is an updated conceptual framework for understanding and researching teachers' specialized knowledge for teaching science. It was developed as a result of the Second PCK Summit held in 2016, building upon and refining the original Consensus Model from 2012.

Key features of the RCM include:

- Three realms of PCK:
 - Collective PCK (cPCK): Shared knowledge among education professionals
 - Personal PCK (pPCK): An individual teacher's knowledge
 - Enacted PCK (ePCK): The specific knowledge used in classroom practice
- Recognition of broader professional knowledge bases that inform PCK, such as content knowledge and pedagogical knowledge.
- Emphasis on the learning context as a mediator of PCK development and application.
- Acknowledgment of amplifiers and filters (e.g., beliefs, orientations) that influence how teachers develop and use PCK.

- Representation of the dynamic nature of PCK development through knowledge exchange between the different realms.
- Recognition of different grain sizes of PCK, from discipline-specific to topic-specific to concept-specific.
- Centrality of pedagogical reasoning in the transformation of knowledge between realms.

The RCM aims to provide a more comprehensive and nuanced understanding of PCK, reflecting the complexity of teacher knowledge and its application in practice. It serves as a framework to guide research, inform teacher education, and support the development of science teachers' professional knowledge.

2.2 PCK Components

Tamir (1988) examined PCK as a teacher knowledge with two fundamental components as SMK and PK. PCK models vary in how they perceive the connection between SMK and PCK (Kind, 2009; Abell, 2008). Actually, researchers propose PCK models rely on Shulman's (1986) model by modifying or adding components. Studies related PCK components could be categorized in to two groups regarding interaction.

One approach is to examine interaction between a component and whole construct of PCK. The studies conducted by Clermont, Krajcik, and Borko (1993) and Van Driel et al. (1998) indicated that teachers' awareness of student comprehension, including preconceived notions, challenges in learning, and styles of reasoning within a particular subject area, aided in the development of their. Similarly, Kamen (1996) and Matese (2005) examined two components and result showed that teachers' knowledge of assessment has effect on their knowledge for teaching and practice.

The other approach is to examine interaction between two components of PCK and researchers focus on how a single component affects another component. For

instance, Brown, Friedrichsen, and Abell (2009) and De Jong, Van Driel, and Verloop (2005) studied the relation between knowledge of student understanding and knowledge of instructional strategies, while not delving into other aspects of PCK.

Magnusson et. al. (1999) proposed a model explaining PCK for science education with five components.

- Orientation toward science teaching
- Knowledge of curriculum
- Knowledge of instructional strategies
- Knowledge of students
- Knowledge of assessment

2.2.1 Orientation toward science teaching

Orientation toward science teaching is knowledge about the goals, values, and orientations towards teaching science effectively. Magnusson et. al. categorized orientation as; ‘process, academic rigor, didactic, conceptual change, activity-driven, discovery, project-based science, inquiry, and guided inquiry’. They put this component in the first order deliberately, because orientations has effect on teachers’ act and decision about teaching.

2.2.1.1 Evolution of Science Teaching Orientations in PCK Research

2.2.1.1.1 Shulman's Original Model of PCK

Shulman's initial model of PCK did not explicitly include science teaching orientations as a component.

2.2.1.1.2 Anderson and Smith (1987)

- Described four general patterns of teachers' orientations toward science teaching and learning: activity-driven teaching, didactic teaching, discovery teaching, and conceptual change teaching.
- Highlighted the prevalence of didactic teaching among teachers at all levels, where teachers primarily present information without considering students' thinking or misconceptions.

2.2.1.1.3 Grossman (1990)

- Introduced the concept of "conceptions of purposes for teaching subject matter" as a component of PCK, positioning it as the overarching component.
- Described this component as encompassing teachers' knowledge and beliefs about the purposes of teaching a subject at different grade levels, influencing their goals for teaching specific subject matter.

2.2.1.1.4 Magnusson et al. (1999)

- Defined science teaching orientations as general ways of conceptualizing science teaching, guiding instructional decisions.
- Identified nine orientations, including activity-driven, didactic, discovery, conceptual change, process, academic rigor, inquiry, project-based science, and guided-inquiry orientations.
- Argued that teachers' orientations toward science teaching are determined by the purpose behind the use of specific teaching strategies.

2.2.1.1.5 Critiques and Refinements

Friedrichsen et al. (2011) criticized the categorization of science teaching orientations proposed by Magnusson et al., highlighting issues such as unclear definitions and relationships between orientations and other components of PCK. Suggested that science teaching orientations should be conceptualized as interrelated sets of beliefs about the goals and purposes of science teaching, science teaching and learning, and the nature of science. The concept of science teaching orientations has undergone refinement and critique over time, reflecting scholars' efforts to better understand the complex interplay between teachers' beliefs, knowledge, and instructional practices within the context of science education. While various models and categorizations exist, ongoing research seeks to clarify and refine the construct of science teaching orientations to deepen our understanding of its role in shaping effective science teaching practices.

2.2.2 Knowledge of Curriculum

Knowledge of curriculum is understanding of the science curriculum, its structure, and the key concepts within it. PCK includes an understanding of the goals and objectives of the curriculum for a specific subject matter. "Teachers with strong PCK are able to interpret and apply curricular goals and objectives to their teaching, ensuring that their instruction aligns with the intended learning outcomes" (Magnusson et al., 1999).

PCK involves understanding how topics and concepts within a subject are related and how they build upon one another across grade levels. Teachers with well-developed PCK possess a profound understanding of the vertical and horizontal curriculum, empowering them to establish connections and scaffold learning effectively (Ball et al., 2008).

PCK enables teachers to adapt and modify the curriculum to meet the needs of diverse learners. Teachers rely on their PCK to make informed decisions about

adjusting the curriculum, such as providing alternative explanations, modifying activities, or differentiating assessments (Park & Oliver, 2008).

PCK guides teachers in effectively implementing the curriculum in their classrooms. "Teachers' PCK influences their instructional planning, pacing, and sequencing of lessons to ensure that students have opportunities to engage with key concepts and develop a deep understanding of the subject matter" (Gess-Newsome, 2015).

2.2.3 Knowledge of Instructional Strategies

Knowledge of instructional strategies is familiarity with various teaching methods and approaches that can be employed effectively in science education. Knowledge of instructional strategies divided in to two categories as; knowledge of subject specific strategies and knowledge of topic specific strategies. Both focus on the same construct but their extent differs from each other. PCK includes knowledge of instructional strategies that are particularly effective for teaching specific subject matter. "Teachers with strong PCK have a repertoire of subject-specific strategies that they can use to represent content, engage students, and address common misconceptions" (Shulman, 1987). PCK guides teachers in selecting and using appropriate representations and explanations to make subject matter comprehensible to students. "Teachers draw upon their PCK to choose and develop representations, analogies, illustrations, and examples that can help students understand complex concepts and ideas" (Ball et al., 2008).

2.2.4 Knowledge of Student

Knowledge of student is understanding the characteristics, misconceptions, and different learning needs of students in the context of science education. Knowledge of student divided in to two categories as; requirements of learning and student difficulties. Students' individual differences is a factor to be considered regarding this component.

PCK includes an understanding of students' prior knowledge, preconceptions, and potential misconceptions related to a specific subject matter. As Hill et al. (2008) note, teachers with strong PCK are able to anticipate and identify students' prior knowledge and misconceptions, which informs their instructional planning and strategies. This understanding allows teachers to design learning experiences that build upon students' existing knowledge and address common misconceptions, promoting conceptual change and deeper understanding.

PCK encompasses knowledge of common learning difficulties that students may encounter when engaging with specific subject matter. As Magnusson et al. (1999) highlight, teachers' PCK guides their capacity to identify and tackle students' learning challenges, enabling them to offer alternative explanations, scaffold learning, or provide targeted support. By anticipating and addressing common learning difficulties, teachers can create more inclusive and effective learning environments that cater to the diverse needs of their students.

2.2.5 Knowledge of Assessment

Knowledge of assessment is understanding various assessment methods and techniques applicable to evaluating students' understanding and progress in science. This component basically focuses on 'what to assess' and 'how to assess'.

In this study I used five components as follow;

- Orientation toward science teaching
 - Process
 - Academic rigor
 - Didactic
 - Conceptual change
 - Activity driven
 - Discovery
 - Project-based science

- Inquiry
 - Guided inquiry
 - Knowledge of curriculum
- Knowledge of goals and objectives
 - Curricular saliency and altering curriculum
 - Vertical curriculum
 - Horizontal curriculum
 - Relation to other disciplines
- Knowledge of instructional strategies
 - Subject specific strategies
 - Subject specific activities
 - Subject specific representations
 - Topic specific strategies
 - Topic specific activities
 - Topic specific representations
- Knowledge of students
 - Pre-requisite knowledge
 - Student difficulties
 - Misconceptions
- Knowledge of assessment
 - Method of assessment
 - Dimensions of science learning to assess

2.3 PCK Studies on Chemistry Topics

In this part, studies that specifically focused on topic-specific PCK studies in chemistry area were summarized. Bucat (2004) argued that PCK in chemistry is highly topic-specific and that research should focus on understanding and developing PCK for specific chemical concepts. Drechsler & Van Driel (2008) investigated the PCK of experienced chemistry teachers in the context of teaching

acid-base chemistry, highlighting the topic-specific nature of their knowledge and strategies. Aydın & Boz (2013) examined the PCK of two experienced chemistry teachers and found that their PCK was highly integrated and topic-specific, with different components of PCK (e.g., knowledge of student understanding, instructional strategies) being closely linked for particular chemical concepts.

Geddis, Onslow, Beynon & Oesch (1993) examined the PCK of two pre-service chemistry teachers and an experienced chemistry teacher regarding the topic of isotopes. Data were collected through interviews and field notes taken during classroom observations. The study found that the pre-service teachers focused solely on the content, struggled to set goals due to insufficient knowledge of the curriculum, experienced time constraints, and tried to convey whatever they were familiar about the topic. In contrast, the experienced teacher had a better command of the curriculum, aimed to impart the key learning outcomes to students, did not face time constraints, and employed strategies to facilitate student understanding.

Shannon (2006) examined the PCK of novice chemistry teachers and those with two years of experience concerning the topic of chemical equilibrium. She aimed to determine how these teachers made instructional decisions while planning lessons, teaching, and reflecting on their practices. The results indicated that the teachers' content knowledge, knowledge of student understanding, and knowledge of instructional strategies influenced their lesson planning decisions and classroom interactions.

Aydın (2012) examined the topic-specific nature of PCK in electrochemistry and radioactivity. Data collection methods included semi-structured interviews, observations, card-sorting activities, field notes, content representations. Study was conducted with two experienced chemistry teachers and results revealed that participants had different PCK. Result of the study revealed the context specific nature of PCK.

Ekiz Kıran (2016) examined the interaction between the orientations of two experienced chemistry teachers on the topic of mixtures and other components of

their PCK. Data for the study were collected through interviews, observations, and field notes. The study found that the teachers' orientations were teacher-centered and were significantly influenced by nationwide exams. It was determined that the teachers believed students did not face any difficulties with the topic of mixtures and did not possess alternative conceptions because they were already familiar with the subject. Furthermore, it was found that the teachers had a highly developed knowledge of the curriculum and that their knowledge of assessment was the component least related to their orientation.

Üner (2016) examined the topic-specific nature of PCK and the teachers' PCK concerning interactions between chemical species and states of matter. Data collection methods included semi-structured interviews, observations, card-sorting activities, field notes, content representations, and a survey administered to 49 students to determine their perceptions of the teachers' PCK. Additionally, semi-structured interviews were conducted with six students. The study found that the components of teachers' PCK varied by topic but also showed similar characteristics in some areas for both topics. The teachers had multiple orientations for both topics, with the dominant orientation being exam-focused. The teachers used the question-and-answer technique to identify students' alternative conceptions but did not check whether these alternative conceptions were resolved. When anticipating that students would struggle, teachers employed topic-specific strategies such as analogies, models, or drawings to concretize the subject, although these were deemed insufficient. It was also concluded that teachers used similar traditional assessment techniques for both topics.

In the study conducted by Akin and Uzuntiryaki-Kondakçı (2018) with three chemistry teachers of varying professional experience, the connections between the components of PCK were examined concerning the topics of reaction rate and chemical equilibrium. Data collection methods included card-sorting activities, content representations, semi-structured interviews, classroom observations, and observation notes. At the end of the study, the PCK of each teacher was analyzed and described, revealing the positive impact of professional experience on PCK and

the topic-specific and personal nature of PCK. Additionally, it was observed that while the teachers used similar lesson plans and teaching materials for the same topics, they differed in the connections they made between PCK components.



CHAPTER 3

METHOD

3.1 Research Questions

- What is the nature of pedagogical knowledge of experienced chemistry teachers for teaching solutions?
- What is the nature of experienced chemistry teachers' knowledge of learner for teaching solutions topics?
- What is the nature of experienced chemistry teachers' knowledge of instructional strategy for teaching solutions topics?
- What is the nature of experienced chemistry teachers' knowledge of curriculum for teaching solutions topics?
- What is the nature of experienced chemistry teachers' knowledge of assessment for teaching solutions topics?

3.2 Research Design

Case study was used in this qualitative research. Case study seeks to answer the question of why and how, without any intervention (Yin, 2003). PCK is a subjective construct and it may vary for each teacher. Case study is convenient to focus on personal differences (Patton, 2002).

Study was conducted in high schools because one of the general characteristics of qualitative studies is to collect data in natural settings (Fraenkel and Wallen, 2006; Patton, 2014). Researcher, who design and implement the study, play a crucial role in qualitative studies because the process is just as important as the result. Researcher should give information about context, which helps researchers for further studies (Leedy & Ormrod, 2001).

3.3 Researcher's Role

In qualitative research process, researcher is responsible for collecting data, s/he is a part of data collection process and s/he could be considered as an “instrument” for data collection process (Denzin & Lincoln, 2008). Role of researcher in this study will be explained regarding; participantness, revealedness, intensiveness, and extensiveness (Patton, 2002).

Participantness, which is the degree of participation, vary from full participant to complete observer. Researcher could have four different role as; complete participant, participant as observer, observer as participant, complete observer (Gold, McCall & Simmons, 1969 as cited in Rubin & Babbie, 2016). I was a complete observer in classroom, I just recorded voice and took notes. I did not interact with student nor teacher in the class.

In order to sustain revealedness, I gave information about purpose of the study to participants. At the beginning of the study detailed information about data collection process of this study was given to participants.

Intensiveness and extensiveness refer the time spent in the context of the study. I visited schools in two semesters. Second semester I visited schools twice a week. I had met with participants at the first semester, one of the participant selection criteria was mutual trust. So, a good relationship was established.

3.4 Ethical Consideration

Study has no effect on participants. Participants just answered question and I made observation class without any interaction with students. Pseudonyms were used for anonymity. Participants were informed about purpose of the study and process of the study. They participated to this study voluntarily. Data were not shared except advisor and coders.

3.5 Limitations

Participants were informed about purpose of the study and they were aware of they would not be criticized nor judged. However, my existence in the class might affect their behavior. School administrations did not allow video recording in the class. I recorded voices and took notes. There may be overlooked participants' behavior during observations.

3.6 Sampling and Participant Selection

Purposeful sampling maintains information-rich cases with desired characteristics for study and this helps to collect rich and beneficial data (Paton, 2002; Mariam, 2009). Participants were selected by the criterion sampling technique which is a purposive sampling method.

PCK is shaped by teachers' experiences and may not be fully formed in the early years of their careers (Lee & Luft, 2018). PCK develops over the course of teaching experience (Park & Oliver, 2008; (Davidowitz & Potgieter, 2016) and experienced teachers have more robust PCK components than inexperienced teachers (Friedrichsen et. al., 2009). Experienced teachers' and novice teachers are different from each other in terms of structure of knowledge base. Experienced teachers' knowledge base is not only more intensive but also more complex (Berliner, 2001). Furthermore, experienced teachers have taught classes with different curricula throughout their careers. The effects of curriculum on PCK may not be understood by inexperienced teachers. Inexperienced teachers may not be able to adapt to the variations presented by students (Shulman, 1978). Berliner (2001) suggests that in order for teachers to be considered experienced, their professional experience should be five or more years. Criteria for the participant selection for this study is experience of teachers and criteria is set for minimum five years' experience.

One semester before the study, I made semi-constructed interviews with all ten chemistry teachers in Kdz. Ereğli district. I introduced myself and gave brief

information about study. I emphasized the importance of their willingness and sincerity. I choose 3 chemistry teachers for the study. In order to assure anonymity pseudonyms were used as teacher 1, teacher 2 and teacher 3 in this study.

Teacher 1 has master degree without thesis in Chemistry Education and he has 13 years' experience as chemistry teacher. Teacher 2 has bachelor degree in Chemistry Education and he has 22 years' experience as chemistry teacher. Teacher 3 has bachelor degree in Chemistry Education and master degree in Chemistry, and she has 15 years' experience as chemistry teacher. All participants are experienced chemistry teachers; they have been teaching all chemistry topics for many years.

3.7 Context of The Study

In qualitative research, behaviors should be studied in real context (Merriam, 1998). Data collected in three public high schools in Kdz. Ereğli Zonguldak. Classrooms are equipped with computers, projectors and smart boards. There were 25-30 students in each class.

3.8 Data Collection Tools

In qualitative studies, variety of sources helps to get deeper information and make realistic conclusion (Creswell, 1998). Besides, due to the contextual nature (Kind & Chan, 2019) and complexity of PCK (Mayhunga, 2020) one single instrument may not be enough to analyze PCK. In this study, data collected with semi-structured interviews, observation, card sorting activity, document analysis and Content representation (CoRe).

3.8.1 Interview

Conducting in-depth interviews is an excellent way to discover what individuals feel or think about a particular subject. It provides an opportunity to discuss past or

ongoing situations with individuals, thereby opening a door to a world that might not be accessible through another method for the researcher (Darlington & Scott, 2002).

Interviews could be categorized as weekly interviews, CoRe interviews and card sorting activity interviews.

Weekly interviews were two fold as pre-lesson interviews and post-lesson interviews. Pre-lesson interviews mainly focused on participants' constructed lesson plan, course flow and ideal beliefs. Post-lesson interviews mainly focused on justification of course flow and instructional decisions in the class. While the pre-lesson interviews sought to answer the question "what", the post-lesson sought to answer the question "why".

Interviews were made mainly in two parts as in pilot study and data collection. Interviews, conducted in pilot study and data collection, focused on participants' beliefs about components of PCK.

3.8.2 Field Notes

Field notes were taken during in class observation. Field notes contain descriptions of the observed situation and consist of descriptive information that allows the person reading the findings of the research to experience the activities observed in the research. It also includes the researcher's own feelings, reactions, and thoughts about the significance of the observed situation (Patton, 2002). We can categorize field notes as descriptive and reflective (Bogdan & Biklen, 1998). Descriptive field notes are completely objective and in chronological order to capture events and interactions. On the other hand, reflective field notes cover personal reflections and personal insights. Reflective field notes help to check whether participants' orientations are working orientations or ideal orientations.

3.8.3 Card Sorting Activity

Purpose of the card sorting activity is to identify participants' science teaching orientations. Teachers' ideal orientations and goals about teaching revealed by performing card sorting activity. Subject specific scenarios were prepared regarding scenarios proposed by Friedrichsen and Dana (2005). Each scenario is related to nine orientations in Magnusson et. al. (1999) model (Table 1). Participants Analyzing the outcomes of the card sorting activity enables researchers to grasp the array of perspectives among teachers, identify recurring themes or trends, and delve into the fundamental beliefs and principles that shape teachers' teaching practices in science. In-class observations and interviews revealed the participants' working orientations.

Table 3.1 Science Teaching Orientations

Science Orientations	Characteristics of Instruction
Process	Help students develop the “science process skills.”
Academic rigor	Represent a particular body of knowledge
Didactic	Transmit the facts of science
Conceptual change	Facilitate the development of scientific knowledge by confronting students with contexts to explain that challenge their naive conceptions
Activity driven	Hands-on experiences for students
Discovery	Students discover the concepts by activities

Project-based science	Students investigate solutions for a problem
Inquiry	Represent science as inquiry
Guided inquiry	Teacher guides for inquiry

3.8.4 CoRe

CoRe helps collect in-depth and descriptive information about PCK directly from teachers, it allows us to gain a unique perspective on teacher practices. Also, CoRe is essential to investigate the topic-specific nature of PCK, because CoRe is a topic specific instrument. CoRe was developed by Loughran et. al. (2004). It is a two-axis table; horizontal axis includes big science ideas and vertical axis factors affecting teacher's decisions (Table.2). CoRe was applied at the beginning of topic. CoRe form was administered to teachers and at the next meeting I made semi-structured interview regarding CoRe. In the interview reason of their reflections were questioned.

Table 3.2 CoRe

Big science ideas (solutions)	Reflections / decisions
What you intend the students to learn about this idea/concept?	
Why it is important for students to know this?	
What else you might know about this idea (that you don't want the students to know yet)	

Difficulties/limitations connected with teaching this idea	
Knowledge about students' thinking that influences your teaching of this idea	
Other factors that influence your teaching of this idea	
Teaching procedures (and particular reasons for using these to engage with this idea	
Specific ways you will use to ascertain students' understanding or confusion around the idea	

3.9 Pilot Study

Purpose of the pilot study was to examine data collection tools. At the end of participant selection process, I studied with a 16 years experienced chemistry teacher. I made observations and conducted interviews. Pilot study helped to prepare check list for class observations and also I refined interview questions.

3.10 Data Analysis

Data analysis is a process intertwined with data collection in qualitative studies (Merriam, 2009). Even if different approaches are followed, it is possible to analyze data analysis in two groups, namely descriptive analysis and content analysis, depending on the depth of the analysis. In descriptive analysis, data are summarized and interpreted according to predetermined themes. On the other hand, the aim of content analysis is to reach concepts that can explain the data and the relationships

between these concepts. Many of human behaviors are not directly observable and measurable, content analysis provides the researcher with the opportunity to access human behavior indirectly (Fraenkel & Wallen, 2006).

In exploratory analysis, the focus is usually not predetermined around a specific target, category, or theme. This method aims to examine data with a broader perspective and discover patterns they contain. It comprehensively gathers, classifies, and analyzes data, followed by the examination of emerging patterns and relationships. On the other hand, deductive analysis is a type of examination centered around a specific focus, category, or theme. Researchers investigate data sets gathered around a particular hypothesis or assumption. This analysis method is used to understand a specific problem or to test a particular thesis (Fraenkel & Wallen, 2006; Azungah, 2018). Therefore, analyses centered on a specific focus, category, or theme are usually part of deductive analysis, while broader explorations aimed at discovering patterns are part of exploratory analysis.

The data were analyzed, in line with Magnusson et. al. (1999) model, by using deductive approach.

3.10.1 Knowledge of Learner

Knowledge of learner was analyzed in three categories as pre-requisite knowledge, student difficulties and misconceptions.

3.10.2 Knowledge of Curriculum

Knowledge of curriculum was analyzed in three categories as ‘knowledge of goals and objectives’ and ‘curricular saliency and altering curriculum’ and ‘relation to other disciplines. Knowledge of goals and objectives was analyzed regarding the key concepts as; aims and limitations. Curricular saliency and altering curriculum were analyzed by two themes as; vertical relations and horizontal relations. Participants

made connections between the topics by associating each topic with the ones covered in earlier grades were coded as 'vertical relations', Besides, participants made connections to topics in the same grade were coded as 'horizontal relations. Relation to other disciplines was analyzed whether topic is suitable to relate to other disciplines.

3.10.3 Knowledge of Instructional Strategies

Knowledge of instructional strategies was analyzed in two categories as subject specific strategies and topic specific strategies. First category has two themes as; subject specific activities and subject specific representations. Second category has two themes as; topic specific activities and topic specific representations.

3.10.4 Knowledge of Assessment

Knowledge of assessment was analyzed in two categories as method of assessment and dimensions science learning to assess. First category has two themes as; formative assessment and summative assessment. Second category has two themes as; the way of assessment and the purpose of assessment.

3.10.5 Orientation to Science Teaching

Orientation to science teaching was analyzed by card sorting activity. Friedrichsen and Dana (2005) proposed scenarios and categories related to these scenarios. Orientation to science teaching were categorized regarding participants' preferred scenarios. Interviews and observations were used to check consistency of the result. Output of the card sorting activity also give ideas about participants' central and peripheral goals.

Participants' decisions for about teaching environment and justifications for these decisions were captured by CoRe. CoRe was applied as Loughran et al., (2004) stated. Data gathered by CoRe and interview.

3.11 Trustworthiness

In qualitative researches trustworthiness includes credibility, transferability and dependability.

Credibility is the degree of conformity of results and reality. Data triangulation, peer debriefing and member check were used to maintain credibility. Different data collection instruments, such as interview, observation, CoRe and card sorting activity, were used, by the way data triangulation was maintained. Data triangulation is an effective way to increase credibility and dependability. Peer debriefing is to allow a person to check data collection procedure and findings of the study (Janesick, 2007). A colleague checked the interview protocol, observation check list, CoRe, card sorting activity and findings of the study. In order to member check, I shared my interpretations and findings with participants and I asked their opinions at the end of the study. They agreed with my findings.

In quantitative research reliability, which is consistency of results, should be maintained. Findings of the research could be replicated in quantitative research; however, it is not probable for qualitative research. In qualitative research consistency of findings with data could be interpreted and it is called as dependability (Merriam, 1998). At the end of the analysis, I have checked data and codes if they are consistent with my findings. Also, a colleague checked the codes. There were some inconsistencies and we come to an agreement for most of the codes. We compared the agreements on coding regarding reliability formula, which was proposed by Miles and Huberman (1994). This formula gives the percentage of number of agreements over total number of agreements and disagreements. At the end of this process, we reached about 90% agreement.

Generalizability of the result is important for both quantitative and qualitative researches. This issue is handled as transferability in qualitative research. Transferability is a degree of what extend the findings could be ensured for similar researches (Merriam, 2009). Due to nature of qualitative study, detailed information about participants, method and findings were given. By the way this study could be transferred to similar researches.

3.12 Keywords and Databases Searched

At the beginning of the study I determined the major key terms as PCK, science teaching orientations, knowledge of learner, knowledge of curriculum, knowledge of assessment, knowledge instructional strategies, chemistry education and science education.

Primary sources were mainly gathered by Science Direct, Educational Resources Information Center, Dissertation Abstracts International in ProQuest and Council of Higher Education Thesis Center. Besides I searched online access journals in Turkey to reach primary sources. I have used books as secondary sources and these books were searched in Middle East Technical University Library.

3.13 Role of Researcher

Researcher is the key element in qualitative researches, because researcher is a kind of instrument in all steps of the research (Merriam, 2009). All data collection instruments were by prepared, applied, and analyzed by me, however I was a non-participant in data collection process. Researchers may take a role ranging from complete participant to non-participant (Creswell, 2009). In class, I was just an observer and I did not interact with students not teacher.

I gave detailed information about purpose of the study to participants. I constructed a time schedule with participants and they were informed by data collection process. I told them my purpose is not to judge nor criticize them.

3.14 Negotiating Entry

I got the necessary permissions from Kdz. Ereğli District National Educational Directorate (DNED) before the study. Firstly, I talked with principles in school and I gave information about my study and they introduced me with chemistry teachers. I introduced myself and gave information about the study. I emphasized the importance of willingness and sincerity to chemistry teachers.

3.15 Ethical Considerations

I applied DNED with thesis proposal for permission before the study. Besides I made conversations with principals of schools. Most of the principals refused video recording in class, so I did not record video. Chemistry teachers are informed about purpose and progress of the study. Chemistry teachers, who hesitated, were not involved to study. Pseudonyms were used to ensure anonymity of the participants.

3.16 Limitations

Participants are informed about aim of the study and they know that my purpose is not judge nor criticize them. Even so they may doubt to express themselves and give detailed information. Besides I attended their classes with their consent, however they are not familiar with someone attend their classes. School administrations did not allow video recording in the class. I recorded voices and took notes. There may be overlooked participants' behavior during observations

Number of participant is not enough to generalize the result of this study. As a matter of fact, aim of this study is not to generalize the results.

3.17 Assumptions

- Participants are open and honest
- Participants are information-rich cases
- Participants have enough topic specific SMK and general PK
- Participants have solid PCK



CHAPTER 4

FINDINGS

4.1 Introduction of Participants

4.1.1 Teacher 1

Teacher 1 is graduated from Chemistry Education department with non-thesis Master degree and he has 12 years' experiences. He worked three years in private schools and nine years in three different public schools. His lesson plans were prepared regarding curriculum and he does not prefer to develop lesson plans if there is no change in curriculum. He uses blackboard for numeric expressions, definition key terms and exercises. He rarely draws diagrams or figures to blackboard. He prefers to referring textbook for visual aids. He does not want to spend time in laboratory.

- Background: Teacher 1 has a strong educational background in chemistry, holding a non-thesis Master's degree in Chemistry Education. With 12 years of teaching experience in both private and public schools, Teacher 1 has had the opportunity to work with diverse student populations and adapt to different school contexts.
- Lesson planning: Teacher 1's reliance on the curriculum for lesson planning suggests a strong alignment with educational standards and objectives. However, the lack of preference for developing lesson plans unless there are curriculum changes may indicate a more static approach to teaching and a potential area for growth in terms of adapting instruction to meet students' evolving needs.
- Instructional strategies: Teacher 1's use of the blackboard for numeric expressions, definitions, and exercises demonstrates a focus on content

delivery and practice. However, the limited use of diagrams and figures and the reliance on textbooks for visual aids may not fully address the diverse learning styles and needs of students.

- Laboratory activities: Teacher 1's avoidance of laboratory activities suggests a limited emphasis on hands-on, inquiry-based learning experiences. This may be an area for development in terms of providing students with opportunities to engage in scientific practices and develop a deeper understanding of chemistry concepts.

4.1.2 Teacher 2

Teacher 2 is graduated from Chemistry Education department with bachelor degree and he has 16 years' experiences as chemistry teachers. He worked in four different cities and seven different public schools. He made lesson plans by developing previous lesson plans. Curriculum reform directs him to develop lesson plans. His primary source for lessons is his lesson plans. He affectively uses blackboard and he does not prefer to use audio visual aids. He draws diagrams and figures to blackboard. Laboratory activities are used to attract attention. His communication with student is very well.

- Background: Teacher 2 holds a bachelor's degree in Chemistry Education and has 16 years of teaching experience across multiple cities and public schools. This diverse experience may have provided Teacher 2 with a broad perspective on student needs and school contexts.
- Lesson planning: Teacher 2's approach to lesson planning involves developing existing plans and adapting to curriculum reforms. This suggests a more dynamic and responsive approach to instruction, where Teacher 2 actively seeks to improve and update teaching materials.
- Instructional strategies: Teacher 2's effective use of the blackboard and incorporation of diagrams and figures demonstrates a commitment to providing visual support for student learning. The preference for lesson plans

as the primary source for lessons suggests a well-organized and structured approach to instruction.

Laboratory activities: While Teacher 2 uses laboratory activities to attract attention, it is unclear whether these activities are consistently integrated into instruction or used to support conceptual understanding. Enhancing the use of laboratory activities to promote inquiry and problem-solving skills could be an area for growth.

4.1.3 Teacher 3

Teacher 3 is graduated from Chemistry Education department with bachelor degree and also she has Master degree in Chemistry department. She has 12 years teaching experiences. She worked in four different cities and five different public schools. She makes lesson plan every semester in the light of curriculum and previous lesson plans. She modifies her lesson plans regarding students' needs and difficulties. She uses blackboard and audio visual aids effectively. She has an electronic portfolio including audio visual aids such as videos, flash animation and pictures. Besides she draws figures to the blackboard. She specified the importance of laboratory activities. She stated that she had almost no opportunity for laboratory activities because of the time limitation.

- Background: Teacher 3 has a strong educational background, with a bachelor's degree in Chemistry Education and a Master's degree in Chemistry. The additional content knowledge gained through the Master's program may enhance Teacher 3's ability to provide in-depth explanations and make connections between chemistry concepts.
- Lesson planning: Teacher 3's approach to lesson planning is comprehensive and adaptive, incorporating curriculum guidelines, previous lesson plans, and modifications based on student needs and difficulties. This suggests a student-centered approach to instruction and a strong understanding of the importance of differentiation.

- Instructional strategies: Teacher 3's effective use of the blackboard, audio-visual aids, and an electronic portfolio demonstrates a commitment to providing diverse and engaging learning experiences for students. The incorporation of videos, animations, and pictures suggests an understanding of the importance of multimedia in supporting student learning.

Laboratory activities: Teacher 3's emphasis on the importance of laboratory activities, despite time limitations, suggests a strong belief in the value of hands-on learning experiences. Continuing to advocate for and incorporate laboratory activities, even in limited capacities, can support the development of students' scientific skills and understanding.

4.2 Knowledge of Learner

Knowledge of learner was analyzed regarding students' pre-requisite knowledge, students' difficulties and misconceptions.

4.2.1 Pre-requisite Knowledge

All three teachers stated ion and ionization concepts as pre-requisite knowledge for the topic in the CoRe. Teacher 1 and Teacher 3 informed students about ion and ionization concepts at the beginning of the lesson. Teacher 3 stated that “Actually I teach the ion and ionization concepts at 9th grade level curriculum, also I recall these concepts at 10th grade in acid-base topic. Students could forget the concepts.” Similarly, Teacher 1 stated that “I gave brief information about ionization to refresh students' knowledge”. Teacher 3 explained the ionization on the blackboard, Teacher 1 informed students superficially. Teacher 2 also claimed the ion and ionization concepts as pre-requisite knowledge but he just asked simple questions about ion and ionizations. He thinks these concepts are thought in previous grade levels and if students remember these concepts there is no need to spend time to teach again.

- Teacher 1:
 - Strategy: Teacher 1 provides a brief refresher on ionization concepts to students.
 - Rationale: The aim is to refresh students' knowledge, acknowledging that they might have forgotten these concepts.
 - Method: Teacher 1 informs students superficially, indicating a belief that only a brief reminder is necessary.
 - Effectiveness: This approach suggests a recognition of the importance of prior knowledge but lacks depth in ensuring all students have a solid understanding of the prerequisite concepts.
- Teacher 2:
 - Strategy: Teacher 2 asks simple questions about ion and ionization to check for understanding.
 - Rationale: Teacher 2 believes these concepts are sufficiently covered in previous grades and only requires a quick check to confirm students' recall.
 - Method: Uses questioning as a method to gauge readiness without detailed explanation.
 - Effectiveness: While efficient, this approach assumes all students have retained the knowledge, which may not be accurate. It might miss identifying students who have misconceptions or gaps in their understanding.
- Teacher 3:
 - Strategy: Teacher 3 revisits and explains ion and ionization concepts on the blackboard.
 - Rationale: Recognizes that students may forget these concepts and therefore integrates a detailed review to reinforce understanding.
 - Method: Combines visual and verbal instruction to ensure students grasp the fundamental concepts.

- Effectiveness: This method is thorough and addresses potential gaps in knowledge, ensuring a stronger foundation for new learning.

All three teachers acknowledge the importance of ion and ionization as prerequisite knowledge. However, their approaches vary significantly in depth and method.

Teacher 1 offers a middle-ground approach by providing a brief review. This strategy is quicker but may not be sufficient for students with weaker prior knowledge.

Teacher 2 relies on students' recall from previous years, which could be effective for high-readiness students but risky for those who might have forgotten or misunderstood the concepts.

Teacher 3 demonstrates a comprehensive understanding of student needs by reviewing concepts in detail, which is likely to be more effective in ensuring all students are on the same page.

All three participants checked students' pre-requisite knowledge, however Teacher 2 did it superficially by questioning whether they remember. Teacher 2 just asked with the phrase "do you remember ...?". In interview I asked why he often used this question. He replied as "my students' readiness level is high. I just want to simply check.". He also stated that this situation was specific to this class. "In the schools I worked in before, the students' pre-requisite knowledge was not at a sufficient level and I spent a lot of time on this." (Teacher 2, daily interviews). Teacher 2 was aware of importance of pre-requisite knowledge, thanks to the high level of readiness of the students, he did not deal with pre-requisite knowledge as other participants.

Mole concept is accepted as pre-requisite knowledge by all teachers. However, they did not give information about the concept nor they did not examine if they remembered the concept. Reason is questioned in interview at the end of the observation. Teacher 1 realized the mole concept as one of the fundamental concepts of chemistry and he claimed that "students already know; they have to know." Teacher 3 and Teacher 2 argued that; if students had forgot the mole concept, this problem would be discovered when dealing with molarity concept.

Role of pre-requisite knowledge was to make the topic easier for Teacher 1 and Teacher 2. On the other hand, Teacher 3 argued the necessity of pre-requisite knowledge for learning the topic.

4.2.2 Student Difficulties

All teachers argued the main difficulty about topic were concentration units and calculations. Teacher 1 thought that; students imagined mathematical operations as complex. In order to handle this difficulty Teacher 1 preferred to solve exercises in class. He stated that; “when I solve more questions, students become more familiar with units and it makes easier for students to solve questions”. Teacher 3 also had the same idea; however, the way of handling is a little bit different. Firstly, she solved a question on the board and she asked other questions to class to solve. When all class solved, she chose a student, who has difficulty in solving, to solve on the board. Teacher 2 did not make extraordinary effort to overcome the difficulty. He suffered from the lack of time and he preferred to assign homework. He thought this difficulty could be overcome by doing more exercises.

Teacher 3 stated the ionization concept as a difficulty because of the abstract nature of abstract nature. She prefers to enrich lesson by visual aids as animations and illustrations. Besides extraction techniques chapter was problematic issue for Teacher 3, because there not fully equipped laboratory in her school and she argued that the concept could be better understood by making experiment. Teacher 2 has fully equipped laboratory and he prepared demonstrations about extractions techniques. Teacher 1 did not prefer to make experiments nor demonstrations and he thought figures in the text book was enough.

In all three classes some students had difficulty to realize unit of solubility. All three teachers were aware of this difficulty and they argued that this issue could not be generalized, it was just about students’ personal traits.

4.2.2.1 Difficulties in Concentration Units and Calculations

- Teacher 1:
 - Identified Difficulty: Students perceive mathematical operations as complex.
 - Strategy: Solves multiple exercises in class.
 - Rationale: Believes that familiarity through practice will ease students' difficulties with units and calculations.
 - Method: Repeatedly solving problems in class to build confidence and competence.
 - Effectiveness: This method helps students gain procedural fluency but may not address underlying conceptual misunderstandings.
- Teacher 2:
 - Identified Difficulty: Agrees that practice is needed but faces time constraints.
 - Strategy: Assigns homework exercises.
 - Rationale: Believes that additional practice outside of class will help overcome difficulties.
 - Method: Homework assignments for additional practice.
 - Effectiveness: While this approach provides extra practice, it may lack the immediate feedback and support that in-class problem-solving offers, potentially leaving misconceptions unaddressed.
- Teacher 3:
 - Identified Difficulty: Similar to Teacher 1, perceives difficulty in students' understanding of calculations.
 - Strategy: Demonstrates problem-solving on the board and involves students in solving additional problems.
 - Rationale: Encourages active participation and provides opportunities for peer learning.

- Method: Solves an example on the board, then asks the class to solve additional problems, selecting students who struggle to solve on the board.
- Effectiveness: This method engages students actively and can help identify and address specific misunderstandings through peer and teacher support.

4.2.2.2 Difficulties in Extraction Techniques

- Teacher 1:
 - Identified Difficulty: Minimal emphasis on practical demonstration.
 - Strategy: Relies on textbook figures.
 - Effectiveness: This approach may be less effective in conveying the full understanding of the techniques, as it lacks interactive and experiential learning components.
- Teacher 3:
 - Identified Difficulty: Lack of practical experience due to inadequate laboratory facilities.
 - Strategy: Emphasizes the need for experiments but is limited by school resources.
 - Effectiveness: The lack of hands-on experience can hinder deep understanding; visual aids partially mitigate this but do not fully replace the value of direct experimentation.

4.2.2.3 Difficulty about Solubility Units

All three teachers recognize that some students struggle with understanding the unit of solubility, attributing this difficulty to individual student traits rather than a generalizable issue. Their strategies include:

- Teacher 1, Teacher 2, and Teacher 3:

- Identified Difficulty: Student-specific challenges with solubility units.
- Strategy: Awareness without a specific targeted approach.
- Effectiveness: This recognition is crucial, but without targeted strategies, some students may continue to struggle. Individualized support or tailored interventions could be more effective in addressing these difficulties.

4.2.3 Misconceptions

Misconception could not be identified by CoRe, because teachers did not state any misconceptions in CoRe. Misconceptions identified in observation. Teacher 2 questioned whether dissolution was chemical reaction or physical change. Teacher 1 asked that question in class; “which solution has higher boiling point; 1 M sucrose solution or 1 M NaCl solution?”. In interview purpose of these questions were asked to Teacher 2 and Teacher 1, both stated the purpose of questions as identify and overcome “common mistakes”.

Teacher 3 was also aware of these misconceptions; however, she did not make extra effort to highlight the misconceptions. She claimed that if all objectives in curriculum completed in detailed, misconception would not be a problematic issue.

4.2.3.1 Identification of Misconceptions

- Teacher 1 asked a question in class regarding the boiling point of different solutions, targeting misconceptions about the properties of solutions.
 - Purpose: Intended to uncover and address misconceptions regarding the factors affecting boiling point.
- Teacher 2 questioned whether dissolution was a chemical reaction or physical change, indicating awareness of potential misconceptions about chemical processes.

- Purpose: Aimed to identify and correct common misconceptions related to the nature of dissolution.
- Teacher 3 was aware of potential misconceptions but did not explicitly highlight them in the lesson.
 - Rationale: Believed that thorough coverage of curriculum objectives would address misconceptions, suggesting a reliance on comprehensive instruction to mitigate misunderstanding.

4.2.3.2 Addressing Misconceptions

- Teacher 2 and Teacher 1: Made efforts to identify and overcome common mistakes through targeted questioning.
 - Purpose: Intended to challenge students' misconceptions and promote deeper understanding of the concepts.
 - Rationale: Recognized the importance of addressing misconceptions to foster accurate understanding and prevent future errors.
- Teacher 3: Did not make specific efforts to highlight or address misconceptions but believed that comprehensive coverage of curriculum objectives would mitigate their impact.
 - Rationale: Relied on thorough instruction to prevent misconceptions, viewing detailed curriculum objectives as sufficient for addressing potential misunderstandings.

4.2.4 Summary of Knowledge of Learner

- All teachers recognize the importance of prerequisite knowledge, particularly for concepts like ions and ionization.
- They differ in how they address this: Teacher 1 and 3 actively review, while Teacher 2 relies more on student recall.

- All identify concentration units and calculations as main difficulties for students.

Teachers vary in their approaches to addressing misconceptions, with Teacher 3 relying more on comprehensive curriculum coverage.

4.3 Knowledge of Curriculum

Knowledge of curriculum was analyzed mainly in three parts as; knowledge of goals and objectives, curricular saliency and altering curriculum and relation with other topics and disciplines.

4.3.1 Knowledge of Goals and Objectives

Teachers indicated all learning outcomes, which were stated in chemistry curriculum, in CoRe. Teachers did not mention any limitation in CoRe. Teacher 3 did not cover normality and formality concepts in class, however Teacher 1 and Teacher 2 told normality concept and made calculations about normality in the class. “It is clearly stated in the curriculum; molarity and molality is taught as concentration units, former concentration units are reminded, normality and formality is not told.” (Teacher 3). Teacher 1’s justification about this issue is that “we teach all concepts in the curriculum but we also give additional information.” On the other hand, Teacher 2 had not perused goals and learning outputs of the curriculum. Teacher 3 was aware of this limitation in the curriculum and she stated “I intentionally did not tell formality concept in line with curriculum. But there are some questions about formality in test books.” In interview.

Teacher 3 defended the necessity of goals and objectives in the curriculum. She thought goals and objectives made easy to plan a lesson and made boundaries. Teacher 1 regarded goals and objectives as a formal requirement. He said that; “Goals and objectives are a part of educational system, so we (teachers) should apply

it.”. Teacher 2 did not prefer to apply curriculum strictly and he realizes the curriculum as rule of thumb.

4.3.1.1 Teacher Approaches to Curriculum Implementation

Teacher 1:

- Approach: Covers all concepts in the curriculum and provides additional information.
- Justification: Believes in teaching all concepts outlined in the curriculum while supplementing with extra information to enhance student understanding.
- Perspective on Curriculum: Views goals and objectives as a formal requirement, emphasizing compliance with the educational system. Teacher 1’s approach indicates a thorough understanding of the curriculum but also a willingness to extend beyond it to enrich student learning.

Teacher 2:

- Approach: Teaches normality but does not strictly adhere to the curriculum.
- Justification: Has not thoroughly reviewed the goals and learning outcomes of the curriculum.
- Perspective on Curriculum: Uses the curriculum as a guideline rather than a strict rule, applying it more flexibly based on perceived needs. This approach can lead to gaps in alignment with curriculum standards but allows for adaptability in teaching practices.

Teacher 3:

- Approach: Does not cover normality and formality, adhering strictly to the curriculum.
- Justification: Aware of the curriculum limitations and intentionally excludes topics not required by the curriculum, despite their presence in textbooks.

Perspective on Curriculum: Strongly defends the necessity of goals and objectives, believing they provide structure and facilitate lesson planning. Teacher 3's adherence to the curriculum reflects a commitment to its boundaries, ensuring alignment with educational standards but potentially limiting exposure to additional relevant concepts.

4.3.2 Curricular Saliency and Altering Curriculum

Order of the topic in the curriculum was asked to teachers. Teacher 3 and Teacher 1 mainly underlined the importance of pre-requisite knowledge. Mole and ionization concepts are in earlier grade level curriculum, and they got worried if students forgot these concepts. So, they added these concepts to lesson plans. Teacher 1 gave information verbally in lesson, Teacher 3 taught these two concepts on the blackboard.

Teacher 3 and Teacher 2 defended the order of sub-topics. Teacher 3 told; "Topic starts with fundamental concepts; I have no difficulty relate concepts to the next one.". In interview Teacher 1 indicated the dissatisfaction about the place of Colligative Properties in the topic. Teacher 1 taught Colligative Properties after Solubility and Factors Affecting Solubility. He told; " in order to teach colligative properties, students should know solubility and this concept directly related to Factors Affecting Solubility" in interview.

The next topic is Chemistry and Energy. They all argued it was not directly related to current topic but both topics are pre-requisite for the next topic; Chemical Rate and Equilibrium.

- Teacher 3 and Teacher 2 defended the order of sub-topics, emphasizing the logical progression of concepts.
 - Rationale: Teacher 3 highlighted the seamless transition from fundamental concepts to more advanced topics, facilitating understanding and retention.

- Teacher 1's Dissatisfaction: Expressed dissatisfaction with the placement of Colligative Properties in the topic sequence, believing it should precede topics like Factors Affecting Solubility.

Reasoning: Identified the necessity for students to grasp solubility concepts before delving into colligative properties, ensuring a logical and coherent learning sequence.

4.3.2.1 Vertical Curriculum

As stated in 'Pre-requisite Knowledge' chapter and 'Curricular Saliency and Altering Curriculum' chapter Teacher 3 and Teacher 1 made link between current topic and the topics in 9th and 10th grade levels as ion, ionization and mole concepts. Both teachers perceive these concepts as pre-requisite. Teacher 2 was also aware of connection these concepts with current topic but he preferred to make connections if students had questions.

4.3.2.2 Horizontal Curriculum

At the beginning of the topic Teacher 2 asked if there was a question mark on students' mind about previous topic. He mentioned just the previous topic. He claimed that if students had difficulties, they would just direct questions.

Teacher 1 did not link the previous topics with the current topic. He thinks only Chemical Calculations is related to current topic, and he claimed that "... calculations are not same, in this topic we just deal with calculations about concentration.". Similarly, Teacher 3 thinks Chemical Calculation topic is related to concentration calculation but as a whole concept and mathematical operations so different. Besides she underlined the connection with Gases topic and current topic in interview. During Effect of Temperature and Pressure chapter, she made connection with Gases topic in class. The same connection was made by Teacher 1

and Teacher 2, but they did not state in interview. When I recall this experiences, they realized they had made connections. Both teachers conceptualize the linking with other topics as standard procedure for all chemistry topics.

Teacher 2: Chemistry is like a spider web. All most every concepts are related to each other, it is valid not only for solution chapter but also for all other chapters.

Teacher 1: I always make explanations by giving examples from other topics. I do not make distinction between chapters, because all are linked to each other. It is not an extraordinary situation.

- Teacher 1:
 - Approach: Does not explicitly link previous topics with the current one but acknowledges the relevance of Chemical Calculations to concentration calculations.
 - Belief: Recognizes the interconnectedness of chemistry concepts and frequently uses examples from various topics to illustrate concepts.
 - Perspective: Views linking topics as a natural part of teaching chemistry, emphasizing the inherent connections between different chapters.
- Teacher 2:
 - Approach: Asks if students have any lingering questions from the previous topic, demonstrating a proactive approach to addressing potential gaps in understanding.
 - Belief: Views chemistry as a network of interconnected concepts, where understanding one topic can enhance comprehension of others.
 - Perspective: Considers linking previous topics with the current one as a standard practice in teaching chemistry, essential for fostering a comprehensive understanding of the subject.
- Teacher 3:

- Approach: Links Chemical Calculations to concentration calculations and makes connections between the current topic and previous ones, such as Gases.
- Belief: Sees the integration of concepts from different chapters as essential for providing a holistic understanding of chemistry.
- Perspective: Considers linking topics as a standard practice and actively makes connections between concepts in class to enhance student understanding.

4.3.3 Relation to Other Disciplines

Teacher 2 informed students about osmosis and gave this example; “Plants absorb water by osmosis” in class. He claimed that interdisciplinary examples could draw attention of students. Teacher 1 and Teacher 3 gave examples about application of concepts in industry and engineering. Teacher 1 told reverse osmosis systems in ships to produce clean water in class. Teacher 3 explained oil extraction from plants and presented an animation about oil extraction from rose.

All teachers argue the positive effect of making relation to other disciplines on students’ attention on class. Teacher 3 has also another point of view, these connections not only attract students to chemistry but also develop curiosity to science. “Solutions topic is fruitful to give examples from other disciplines. I care to give examples from other disciplines and make connections. By the way I could canalize students to think. They like think hard if they become curious” (Teacher 3)

- Teacher 1:
 - Approach: Gives examples of reverse osmosis systems in ships to produce clean water, showcasing the practical applications of chemistry in engineering and industry.

- Belief: Emphasizes the importance of relating chemistry concepts to real-world contexts to enhance student understanding and appreciation for the subject.
- Teacher 2:
 - Approach: Provides an example of osmosis in plants to illustrate the concept, aiming to draw students' attention by highlighting its relevance to biology.
 - Belief: Views interdisciplinary examples as effective tools for capturing student interest and demonstrating the real-world applications of chemistry concepts.
- Teacher 3:
 - Approach: Presents examples of oil extraction from plants and utilizes animations to illustrate the process, emphasizing the interdisciplinary connections between chemistry and other fields.
 - Belief: Sees the integration of examples from other disciplines as a means to not only attract students to chemistry but also foster curiosity and critical thinking about scientific phenomena.
- Shared Perspective:
 - Positive Effect: All teachers acknowledge the positive impact of integrating interdisciplinary examples on student engagement and attention in class.
 - Development of Curiosity: Teacher 3 particularly highlights how these connections can stimulate students' curiosity and encourage them to think critically about scientific concepts.

4.3.4 Summary of Knowledge of Curriculum

- Teachers show varying levels of adherence to curriculum guidelines, with Teacher 3 being the strictest.

- All make connections to other topics and disciplines, recognizing the interconnected nature of chemistry concepts.
- They differ in their views on curriculum flexibility, with Teacher 2 being the most flexible.

4.4 Knowledge of Instructional Strategies

4.4.1 Subject Specific Strategies

Teachers do not used any subject specific strategies.

4.4.2 Topic Specific Strategies

Topic specific strategies were analyzed in two parts; Topic Specific Activities and Topic Specific Representations.

4.4.2.1 Topic Specific Activities

Only Teacher 2 had fully equipped laboratory and he conducted just one demonstration experiment for the topic. He thought experiments took a lot of time. He stated that “Experiment is a part of chemistry and it is attractive. But curriculum is overloaded and activities take lots of time.” Teacher 1 had also laboratory but he did not prefer to make an activity in laboratory. His perspective toward laboratory activities was similar with Teacher 2, and his reason was overloaded curriculum and time limitations. Besides his laboratory is not fully equipped and he had doubt about safety issues and accidents. He stated that “If I have more lesson to cover all issues in the topic and if I could have better laboratory, I want to conduct experiments.”. Teacher 3 was the most enthusiastic about laboratory activities, but she did not have a laboratory. She stated that; “Laboratory gives opportunity to learn by doing, by experiencing.”. She has a video archive, which includes demonstrations and

animations for all chemistry topics. For instance, she represented a video of experiment related to effect of temperature and pressure on solubility of gases.

Teacher 3 and Teacher 1 argue the advantage of audio-visual aids, such as flash animations and videos. Teacher 1 think audio visual materials could compensate for hands on activities. He thinks audio visual materials are a way of effective time management. On the other hand, Teacher 3 complains about inadequacy of facility.

Teacher 3: Videos are so useful to explain issues, but it is not affective as laboratory experiments. Learning by doing is much more powerful than learning by watching. In class I showed a video in order to students think whether temperature and pressure has effect on solubility. They generated ideas but they could not experiment the concept.

- Teacher 1:
 - Approach: Chooses not to conduct laboratory activities due to similar reasons as Teacher 2, including an overloaded curriculum, time limitations, and safety concerns.
 - Perspective: Recognizes the potential benefits of hands-on experiments but believes that audiovisual materials can compensate for the lack of practical activities and help manage time more effectively.
- Teacher 2:
 - Approach: Conducts only one demonstration experiment due to time constraints and an overloaded curriculum.
 - Perspective: Acknowledges the value of experiments in chemistry but cites curriculum demands and time limitations as barriers to conducting more activities in the laboratory.
- Teacher 3:
 - Approach: Expresses enthusiasm for laboratory activities but lacks access to a laboratory.

- Perspective: Highlights the importance of experiential learning and believes that hands-on activities in the laboratory offer unique opportunities for students to learn by doing. Relies on audiovisual aids, such as videos and animations, as alternatives to laboratory experiments but acknowledges their limitations compared to hands-on experiences.
- Shared Perspectives:
 - Value of Audiovisual Aids: Teachers 1 and 3 recognize the advantages of using audiovisual materials, such as flash animations and videos, in enhancing student understanding and managing time effectively.
 - Limitations of Facilities: Teacher 3 voices concerns about the inadequacy of facilities for conducting laboratory activities, highlighting the need for better resources to support hands-on learning experiences.

4.4.2.2 Topic Specific Representations

All three teachers used graphs in Factors Affecting Solubility and molecular representations in Solvent-Solute Interactions. I observed, Teacher 2 and Teacher 3 draw fundamental graphs on the board and they asked students to draw more complex ones in lesson. On the other hand, Teacher 1 did not involve students to this process, if students had no difficulty. Teacher 1 said; “when students had difficulty to understand exercises, I call a student to solve exercise on the board. If he has difficulty we solve together.”.

Teacher 2 used analogy about saturated solutions; “There are 30 chairs in the classroom. If there are 20 students, classroom is not saturated. What should we know?... We should add student... How many students.... 10 students. Can we add 11 students?”. However, he did not emphasize the limitations of his analogy. Teacher 3 has used a similar analogy; “Bus has 50 seats and there are 25 passengers in the

bus. It is unsaturated bus. How many passenger should get in to saturate the bus?.... What happens if there are more than 50 passengers in the bus?...". She made connection with standing passengers and precipitation. Teacher 1 did not used any analogies in the class. In interview he stated that; "Analogy is an effective method to student understand better. I do not do a plan for analogies, I use analogies if it comes to my mind."

4.4.2.2.1 Graphs

- Teacher 1: Draws graphs on the board without involving students unless they encounter difficulty, then collaborates with students to solve exercises.
 - Approach: Prioritizes addressing student difficulties through collaborative problem-solving, providing targeted support as needed.
- Teacher 2 and Teacher 3: Draw fundamental graphs on the board and engage students in drawing more complex ones during the lesson, promoting active learning and reinforcing graph interpretation skills.
 - Rationale: Encourage student involvement in graph construction to deepen understanding and build graphing proficiency.

4.4.2.2.2 Analogies

- Teacher 1: Does not use analogies as a planned instructional strategy but may employ them spontaneously if deemed helpful.
 - Perspective: Recognizes the effectiveness of analogies in enhancing student understanding but does not incorporate them systematically into teaching.
- Teacher 2 and Teacher 3: Employ analogies to explain concepts such as saturated solutions, using relatable scenarios like classroom occupancy and bus seating capacity.

- Approach: Utilize analogies to simplify complex concepts and facilitate student comprehension, although limitations of analogies may not be explicitly addressed.

4.4.2.2.3 Shared Perspectives

- Value of Graphs and Analogies: All teachers acknowledge the benefits of using graphs and analogies in teaching chemistry concepts, although their approaches vary.
- Student Engagement: Teacher 2 and Teacher 3 actively involve students in graph construction and analogy exploration, fostering engagement and participation in the learning process.
- Adaptability: Teacher 1 demonstrates flexibility in incorporating instructional strategies based on student needs, emphasizing collaborative problem-solving to address difficulties.

4.4.3 Summary of Knowledge of Instructional Strategies

- Use of laboratory activities is limited, often due to time constraints or lack of facilities.
- All use visual aids and representations, but to varying degrees.
- Teacher 2 and 3 are more likely to use analogies and engage students in graph construction.

4.5 Knowledge of Assessment

Magnusson et. al. (1999) proposed two domains for knowledge of assessment as; methods of assessment and dimensions of science learning to assess.

4.5.1 Method of Assessment

Available methods for assessment about the topic was questioned in CoRe. Observations and interviews are also data sources for method of assessment.

Teachers' method of assessment could be categorized as formative assessment and summative assessment. Informal questioning was employed by all three teachers as formative assessment. They asked short answer questions;

- at beginning of the lesson to recall the information about the last lesson,
- during the lesson to test if students had difficulty and also to take attention
- at the end of the lesson to check if students understood the lesson

Teacher 1 and Teacher 2 daily assigned homework to students as a tool of formative assessment. The homework involved the questions in the textbook and multiple choice questions. Teacher 1 said that; "If I do not give homework, most of the students are not willing to study chemistry.". Teacher 2 said that; "I gave homework; you can think it as exercises. The more they exercise, the more successful they are...". Both teachers did not grade daily homework, they just checked if students completed or not. Teacher 3 also assigned homework. Teacher 3 said that; "Homework is essential for practicing and learning. Besides I can realize the misunderstood concepts.".

Teacher 1 did not assign any term project. Teacher 2 assigned students to search and report colligative properties. When I asked the purpose of this assignment he said; "Name is complex and scary. Colligative... They are not familiar with it.". His experience had on his decision. Teacher 3 had presented animations and videos, and at the end of the visual show she assigned students to search visual materials on the web. She said; "Making research on the web may motivate students and they also they develop a skill to discover information.".

All three teachers applied written exam at the end of the topic as summative assessment. Criteria, when preparing exam, was questioned in interview. Teacher 2

prepared exam regarding textbook, Teacher 3 prepared exam regarding learning outcomes and Teacher 1 prepared exam regarding lesson plan.

The assessment methods used by the teachers for evaluating student learning about the topic exhibit a combination of formative and summative approaches.

4.5.1.1 Formative Assessment

4.5.1.1.1 Informal Questioning

- Used by all teachers: Employed at various points during the lesson to gauge student understanding.
- Purpose: Assess student comprehension, identify difficulties, and maintain student engagement.
- Implementation: Short-answer questions posed at the beginning, during, and end of the lesson.

4.5.1.1.2 Homework Assignments

- Teacher 1 and Teacher 2: Assign daily homework, consisting of textbook questions and multiple-choice exercises.
- Purpose: Reinforce learning and encourage consistent study habits.
- Implementation: Homework completion checked regularly, but not graded, focusing on practice rather than assessment.
- Teacher 3: Also assigns homework to provide additional practice opportunities and identify misunderstood concepts.
- Purpose: Support learning and serve as a diagnostic tool for identifying areas of difficulty.

4.5.1.1.3 Term Projects

- Teacher 2: Assigns a project on colligative properties, aimed at increasing student familiarity with the topic.
- Purpose: Encourage independent research and deepen understanding of complex concepts.
- Teacher 3: Integrates research tasks into lessons by assigning students to search for visual materials online.
- Purpose: Foster information literacy skills and engage students in active learning.

4.5.1.2 Summative Assessment

4.5.1.2.1 Written Exams

Written exams were employed by all teachers and which were administered at the end of the topic to assess overall understanding.

- Teacher 1: Develops exam based on the lesson plan.
 - Purpose: Evaluate alignment with instructional goals and objectives set out in the lesson plan.
- Teacher 2: Prepares exam based on textbook content.
 - Purpose: Evaluate knowledge acquisition and understanding of core concepts covered in the curriculum.
- Teacher 3: Designs exam based on learning outcomes.
 - Purpose: Assess mastery of specific skills and knowledge as outlined in curriculum objectives.

4.5.1.3 Comparison and Analysis:

4.5.1.3.1 Formative Assessment:

All teachers use informal questioning to gauge student understanding, demonstrating a commitment to ongoing assessment and responsive teaching practices.

Homework assignments are used to varying degrees, with Teacher 1 and Teacher 2 emphasizing practice and reinforcement, while Teacher 3 focuses on identifying misconceptions and providing additional practice opportunities.

4.5.1.3.2 Summative Assessment:

Written exams serve as the primary summative assessment method for all teachers, but the criteria for exam preparation vary.

Teacher 2 and Teacher 3 align their exams with specific criteria such as textbook content and learning outcomes, ensuring assessment is directly linked to instructional objectives. Teacher 1's exam preparation is guided by the lesson plan, reflecting a focus on evaluating student mastery of planned instructional activities.

4.5.2 Dimensions of Science Learning to Assess

Mainly three questions were directed to teachers;

- What do you assess?
- How do you assess?
- Why do you assess? (What is the purpose of assessment?)

Depending on participants' reflections, what they assess and what purpose they assess are given in Table 3

Table 4.1 Participants' Dimensions of Science Learning to Assess

What do they assess?	Teacher 1	Teacher 2	Teacher 3
Pre-requisite knowledge	Facilitator	Facilitator(superficially)	Meaningful learning
Difficulty in learning	Meaningful learning	-	Meaningful learning
Academic performance	Grading	Grading	Grading

All three teachers asked questions at the beginning of lesson to test whether students have preliminary knowledge, during the lesson to test if students had difficulty and also to take attention and at the end of the lesson to check if students understood the lesson. Teachers prefer informal questioning to assess prior knowledge and to examine whether students understand the topic.

Teacher 2 implies the effectiveness of direct observation. On the other hand, Teacher 1 and Teacher 3 pointed out the weakness of direct observation.

Teacher 3: I cannot tell whether students have misconceptions or not by direct observations. Direct observations give clues about students' interest to lesson.

Teacher 1: Direct observation is helpful if all students are curious about topic and all of them are willing to participate class.

Teacher 3 especially underlined the importance of homework and exams as a measurement tool and facilitator for feedback. Teacher 1 and Teacher 2 did not mention about feedback. I especially asked them the place of feedback in assessment. Teacher 1 gives feedback just by after the exam.

Teacher 1: The next week of the written exam I solve questions on the board and I give papers to students. If they have questions I give explanations.

Teacher 2: I often give daily life examples. For instances I asked “what happens if you shake soda bottle and open it?”. I prefer to give feedback after directing questions.

Teacher 2 asks questions related daily life. If students could not give correct answer or if they could not explain the phenomena, he assigns the question as homework.

Teacher 2 and Teacher 1 are mainly focused on academic achievement and they told knowledge about the topic could be assessed by exams. Teacher 3 also use exams to assess academic achievement but she thinks exam is an opportunity for students to think and learn.

Teacher 3: Written exams are usually made for grading. I prefer to ask engrossing questions and this topic is so appropriate. This is a question for written exam; ‘Why soda does not sparkle when lid is closed?’.

Teacher 1 and Teacher 3 also underlined the importance of the curriculum about. “Goals and objectives in the curriculum direct me when I was preparing exams. It is a kind of outline for questions.” (Teacher 3).

Teacher 1 prepare exam questions without leaving boundaries of the curriculum. On the other hand, Teacher 3 does not draw sharp boundaries, she considered students’ needs

4.5.3 Assessment Strategies

The teachers employ a variety of assessment strategies and feedback practices to check student understanding and provide support.

4.5.3.1 Informal Questioning

- All Teachers: Utilize informal questioning at the beginning, during, and end of the lesson to assess prior knowledge, identify difficulties, and check understanding.

4.5.3.2 Direct Observation

- Teacher 2: Emphasizes the effectiveness of direct observation for understanding student engagement and interest in the lesson.
 - Rationale: Views direct observation as a valuable tool for gauging student interest but acknowledges its limitations in detecting misconceptions.
- Teacher 1 and Teacher 3: Highlight the weaknesses of direct observation for assessing misconceptions or student understanding.
 - Rationale: Direct observation may not reveal students' internal thought processes or misconceptions, limiting its utility as a diagnostic tool.

4.5.3.3 Homework and Exams as Assessment Tools

- Teacher 1 and Teacher 2: Primarily focus on academic achievement and use exams as the primary assessment tool.
 - Feedback Practices: Teacher 1 provides feedback after exams by addressing student questions in subsequent classes.
 - Homework Practices: Teacher 2 assigns homework based on daily life examples and uses incorrect responses as indicators for further study.
- Teacher 3: Utilizes homework and exams as assessment tools but emphasizes their role in facilitating feedback and promoting student learning.
 - Feedback Practices: Seeks to engage students in critical thinking through exam questions that prompt deeper understanding.
 - Homework Practices: Uses homework to reinforce learning and identify misconceptions, viewing it as an opportunity for practice and feedback.

4.5.3.4 Curriculum Alignment

- Teacher 1: Adheres closely to curriculum guidelines when preparing exam questions, ensuring alignment with instructional goals and objectives.
 - Rationale: Views the curriculum as a framework for assessment, providing clear guidelines for exam preparation.
- Teacher 3: Considers student needs and preferences when designing exams, incorporating engrossing questions that promote critical thinking.
 - Rationale: Values flexibility in assessment design, recognizing the importance of adapting to students' learning styles and interests.

4.5.4 Summary of Knowledge of Assessment

- All participants use a mix of formative (questioning, homework) and summative (exams) assessments.
- They differ in their exam preparation approaches, reflecting their teaching orientations.
- Feedback practices vary, with Teacher 3 emphasizing its role in promoting learning.

4.6 Orientation to Science Teaching

Teacher 1 preferred process, academic rigor and didactic orientations in card-sorting activity. He stated that “these three scenario are suitable for solubility topic because curriculum direct me to teach in this way. Also these scenarios are appropriate to prepare students for exam”. His central goals are to provide necessary knowledge as dictated in curriculum and to prepare students for university entrance exam. His peripheral goals are higher-order thinking skills.

Teacher 2 preferred process, academic rigor, conceptual change, activity driven, discovery and inquiry as a result of card-sorting activity. He stated the importance

of critical thinking and he thinks it could be maintained by inquiry. He said that “we have to give opportunity students to discover and also we have to force them. They should think all possibilities, for instance molar is not concentration unit, if I always give examples with just one unit students do not care other units”. His central goals are to help learners discover rather than providing knowledge and to develop higher-order thinking skills. Contrarily to other participants, giving necessary knowledge for university entrance exam is not central goal, because he thinks that if students have higher-order thinking skills and aware of the ways of access information eventually students could achieve. His peripheral goals are to relate chemistry to daily-life and provide scientific literacy.

Teacher 3 preferred conceptual change, activity driven, discovery and project based orientations in card-sorting activity. She said that “these scenarios are ideal and essential for this topic; however, it is almost impossible teach in this way. Because students focus on university entrance exam, they want to get correct result instead of learning and applying”. Her central goals are to prepare students for university entrance exam and to attract their attention to chemistry. Her peripheral goal is to develop science-process skills.

Table 4.2 Participants' Science Teaching Orientations

Science Orientations	Teacher 1	Teacher 2	Teacher 3
Process	+	+	
Academic rigor	+	+	
Didactic	+		
Conceptual change		+	+
Activity driven		+	+
Discovery		+	+
Project-based science			+

All three teachers are aimed to prepare students for university exams. This issue affects Teacher 1's and Teacher 3's orientations. Teacher 2 is very confident that his orientations will make the students succeed.

All teachers aim to prepare students for university entrance exams, but the extent to which this goal influences their teaching orientations varies. Teacher 1 and Teacher 3 prioritize exam preparation as central goals, aligning their teaching strategies with the curriculum and exam requirements. Teacher 2 values critical thinking and inquiry-based learning, believing that these skills are crucial for long-term success beyond exams.

Teacher 1 focuses on content delivery and academic rigor, emphasizing the importance of meeting curriculum standards and ensuring exam readiness. Teacher 2 emphasizes discovery learning and critical thinking, prioritizing student engagement and conceptual understanding over rote memorization. Teacher 3 recognizes the value of inquiry-based learning but feels constrained by student priorities and exam pressure, striving to balance exam preparation with engaging and practical learning experiences.

4.6.1 Comparison of Teacher Orientations in Card-Sorting Activity

- Teacher 1:
 - Preferred Orientations: Process, academic rigor, and didactic.
 - Central Goals: Provide necessary knowledge as per curriculum guidelines and prepare students for university entrance exams.
 - Peripheral Goals: Foster higher-order thinking skills.
 - Rationale: Emphasizes adherence to curriculum directives and exam preparation, prioritizing content delivery and academic achievement over critical thinking or inquiry-based learning.

- Teacher 2:
 - Preferred Orientations: Process, academic rigor, conceptual change, activity-driven, discovery, and inquiry.
 - Central Goals: Facilitate discovery learning and develop higher-order thinking skills.
 - Peripheral Goals: Relate chemistry to daily life and promote scientific literacy.
 - Rationale: Advocates for critical thinking and inquiry-based learning, believing that fostering curiosity and exploration leads to deeper understanding and long-term academic success beyond exam preparation.
- Teacher 3:
 - Preferred Orientations: Conceptual change, activity-driven, discovery, and project-based.
 - Central Goals: Prepare students for university entrance exams and engage students in chemistry.
 - Peripheral Goals: Develop science-process skills.

Rationale: Recognizes the value of inquiry-based learning but finds it challenging to implement due to student focus on exam outcomes. Prioritizes exam preparation while aiming to foster an interest in chemistry and develop practical science skills.

4.6.2 Summary of Orientation to Science Teaching

- Teacher 1 leans towards more traditional, didactic approaches.
- Teacher 2 emphasizes inquiry and critical thinking.
- Teacher 3 recognizes the value of inquiry-based methods but feels constrained by exam pressures.

CHAPTER 5

DISCUSSION & CONCLUSION

In this chapter findings of the study were analyzed regarding literature. In the light of the discussed points, the conclusions of the results were made. This chapter consists of five headings as; knowledge of learner, knowledge of curriculum, knowledge of instructional strategies, knowledge of assessment and orientation to science teaching.

5.1 Knowledge of Learner

All three participants checked students' pre-requisite knowledge, however Teacher 2 did it superficially by questioning whether they remember. Teacher 2 just asked with the phrase "do you remember ...?". In interview I asked why he often used this question. He replied as "my students' readiness level is high. I just want to simply check.". He also stated that this situation was specific to this class. "In the schools I worked in before, the students' pre-requisite knowledge was not at a sufficient level and I spent a lot of time on this." (Teacher 2, daily interviews). Teacher 2 was aware of importance of pre-requisite knowledge, thanks to the high level of readiness of the students, he did not deal with pre-requisite knowledge as other participants.

Teacher 2's approach to checking students' prerequisite knowledge illustrates the practical application of understanding student learning. Despite using a seemingly superficial method asking, "Do you remember?". Teacher 2's strategy was informed by an understanding of the high readiness level of the students in his current class. He noted that in previous teaching contexts with lower readiness levels, he had to spend more time addressing prerequisite knowledge. This example demonstrates that effective teaching is context-specific and responsive to students' needs. Teacher 2's adaptation of his approach based on student readiness reflects a nuanced

understanding of student learning and the importance of flexibility in instructional strategies.

Piaget (1972) defined pre-requisite knowledge as the foundation upon which learners actively construct new meaning and understanding (Piaget, 1972). Only Teacher 2 made connections between knowledge of learner and constructivism. Teacher 2 told that; “I was not aware of constructivism till in-service training program.... I realized the importance of the pre-requisite knowledge for constructivism.”. However, Teacher 3 did not emphasize the constructivism, she argued the necessity of pre-requisite knowledge for meaningful learning.

Teachers, who have strong PCK, could adapt their instructional strategy by providing additional explanations or utilizing alternative representations to assist students in developing the essential foundational knowledge before introducing new content (Kind, 2009). Teacher 1 and teacher 3 have different strategies to deal with pre-requisite knowledge. Even though they follow different strategies, we can say that both teachers have strong PCK, regarding Kind (2009).

Teacher 1 regard pre-requisite knowledge as a facilitator. Besides he thought that solving more questions could help to overcome students’ difficulties and he preferred to solve questions on board. Teacher 3 also argued this issue but in a different way. Firstly, she solved a question on board and then she asked other questions to class to solve. Students’ responses affect her decisions and strategies. Assessing pre-requisite knowledge allows teachers to differentiate their instructional strategies and provide appropriate support (Tomlinson et. al., 2003). Pre-requisite knowledge affected her instructional decisions.

All participants underlined the importance of experience about identifying pre-requisite knowledge. “... at beginning of the teacher career, I did not check students’ pre-requisite knowledge. I had to go back when students had difficulty “(Teacher 2, daily interviews). Engaging with student difficulties may allow teachers to refine their PCK by adapting their explanations, representations, and instructional strategies to better meet the needs of their students (Loughran et al., 2012).

Teacher 3 gave importance over time and out of necessity. “students at the school, where I worked before, were low achievers. Pre-requisite knowledge was a problematic issue and I had to diversify my teaching...” (Teacher 3, daily interviews) Teachers engage in instructional practices and interact with students, they gain insights into students' prior knowledge, misconceptions, and learning difficulties (Loughran et al., 2012). PCK helps teachers differentiate their instruction to meet the needs of students with varying levels of understanding and different misconceptions. Teachers with strong PCK are better equipped to modify their teaching strategies regarding individual students' difficulties (Park & Oliver, 2008).

The development of PCK is a continuous process shaped by teachers' experiences with students' difficulties and misconceptions. As teachers encounter and address these challenges in their classrooms, they refine their PCK and enhance their effectiveness in fostering student understanding.

Teacher 2 suffered from lack of time and he did not prefer solve much questions in class. In all three classes some students had difficulty to realize unit of solubility. All three teachers were aware of this difficulty and they argued that this issue could not be generalized, it was just about students' personal traits.

The approaches taken by Teacher 1, Teacher 2, and Teacher 3 to address prerequisite knowledge of ions and ionization demonstrate different levels of engagement with students' prior understanding. Teacher 3's thorough method suggests a robust application of PCK by ensuring foundational knowledge is solidified, while Teacher 2's strategy, though efficient, risks overlooking gaps in student understanding. Teacher 1's approach provides a compromise but may require more in-depth assessment to ensure effectiveness. These variations underscore the importance of tailoring instructional strategies to meet the diverse needs of students, ensuring a solid foundation for new learning.

The varied approaches of the teachers highlight different aspects of Magnusson's PCK model, particularly in relation to knowledge of student understanding:

- Teacher 1 emphasizes procedural practice to build familiarity, reflecting a focus on procedural fluency but potentially lacking in addressing deeper conceptual understanding.
- Teacher 2 relies on homework for additional practice due to time constraints, reflecting an understanding of the need for practice but potentially missing the immediate feedback and interactive support necessary for addressing misconceptions.
- Teacher 3 combines demonstration with active student participation, integrating visual aids to address abstract concepts, reflecting a comprehensive approach to student understanding and engagement.

The analysis of the different teachers' approaches to addressing students' difficulties in chemistry highlights the importance of PCK on student learning. In this study, the teachers demonstrate varying levels of PCK in their strategies for addressing students' challenges with concentration units, calculations, ionization concepts, and extraction techniques.

Teacher 3's approach shows a strong application of PCK by incorporating visual aids and interactive problem-solving. This strategy aligns with the understanding that students often struggle with abstract concepts and can benefit from visual representations and hands-on engagement (Johnstone, 1991). By providing multiple modes of representation and opportunities for active learning, Teacher 3 is addressing both the procedural and conceptual difficulties that students may face. This approach is supported by research showing that multimodal instruction and interactive learning can enhance student understanding and retention of complex science concepts (Tytler, 2007).

In contrast, Teacher 1's emphasis on repeated practice may help students build familiarity with the procedures but may not adequately address their conceptual understanding. While practice is important for developing procedural fluency, it should be balanced with activities that promote deeper conceptual knowledge (Bransford, Brown, & Cocking, 2000). Teacher 1 could enhance their approach by

incorporating more explanations, real-world examples, or guided inquiry activities that help students connect the procedures to underlying concepts.

Teacher 2's reliance on homework as the primary strategy for addressing difficulties acknowledges the need for students to practice and reinforce their learning. However, this approach may not provide sufficient in-class support for students who are struggling. Homework can be an effective tool for extending learning, but it should be complemented by interactive classroom activities, feedback, and differentiated instruction (Marzano, Pickering, & Pollock, 2001). Teacher 2 could strengthen their approach by incorporating more collaborative problem-solving, guided practice, or targeted support during class time.

The varying effectiveness of these teachers' strategies underscores the importance of developing and applying PCK to address students' specific needs. As Magnusson, Krajcik, and Borko (1999) noted, PCK includes knowledge of students' understanding of science, knowledge of instructional strategies, and knowledge of assessment. Effective teachers draw upon these knowledge bases to design instruction that is responsive to students' difficulties, misconceptions, and learning preferences.

Moreover, the development of PCK is an ongoing process that requires teachers to continually reflect on their practice, engage with educational research, and adapt their approaches based on student feedback and outcomes (Park & Oliver, 2008). As the teachers in this example continue to refine their strategies and deepen their understanding of student needs, they can further enhance their ability to support student learning in chemistry.

The teachers demonstrate varying approaches to the identification and addressing of misconceptions in student learning. While Teacher 2 and Teacher 1 actively sought to uncover and correct common misconceptions through targeted questioning, Teacher 3 relied on comprehensive instruction to mitigate the impact of misconceptions. Addressing misconceptions is crucial for promoting accurate understanding and fostering deeper learning among students. Each teacher's

approach reflects their unique perspectives on teaching and learning, highlighting the importance of targeted interventions to address student misconceptions effectively.

In conclusion, the teachers' approaches to addressing student difficulties in chemistry demonstrate the importance of applying PCK to create effective, responsive instruction. By incorporating strategies that target both procedural and conceptual understanding, providing interactive support, and continually refining their methods based on student needs, teachers can help students overcome challenges and develop a robust understanding of complex science concepts.

- Teachers are aware of the importance of pre-requisite knowledge
- Ion, ionization and mole concepts are pre-requisite knowledge for the topic
- Concentration units and calculation are difficult concepts for students
- Students have difficulty in abstract phenomena
- Difficulties could be overcome by exercises and laboratory activities

Teachers are aware of misconceptions but they do not have specific methods to overcome this problematic issue.

5.2 Knowledge of Curriculum

5.2.1 Curriculum as a Knowledge Organizer

While curriculum may not be the major factor influencing PCK (Park & Chen, 2012), Arzi and White (2007) emphasize its role as a 'knowledge organizer' and its impact on subject matter knowledge. Teacher 3's utilization of the curriculum as a knowledge organizer and her consideration of it as an indispensable part of education highlight the importance of curriculum in structuring and guiding the teaching and learning process.

5.2.2 Awareness of Curriculum Reforms

All participants' awareness of the importance of the curriculum and their efforts to follow reforms demonstrate their commitment to staying current with educational developments. This awareness is crucial for adapting their teaching practices to align with the latest research and best practices in science education.

5.2.3 Curricular Saliency and Altering Curriculum

Teacher 3 and Teacher 1's preference for starting lessons by testing prerequisite knowledge and their willingness to spend time on this task reflect their understanding of the importance of building upon students' prior knowledge. In contrast, Teacher 2's approach, which is influenced by his students' strong prerequisite knowledge, highlights the role of context and knowledge of learners in shaping instructional decisions (De Miranda, 2008; Friedrichsen et al., 2011).

5.2.4 Vertical and Horizontal Curriculum Connections

Teacher 3 and Teacher 1's efforts to make connections between previous and current topics (vertical curriculum) and across different disciplines (horizontal curriculum) demonstrate their understanding of the interconnectedness of science concepts. Teacher 2's greater emphasis on these connections suggests a more comprehensive approach to teaching chemistry. These practices align with research that emphasizes the importance of integrating concepts and promoting transfer of knowledge across domains (Yendi, 2019).

5.2.5 Curriculum and Teachers' Orientations

The varying degrees of emphasis placed on the curriculum by the participants, with Teacher 1 valuing it the most and Teacher 2 the least, suggest a complex relationship

between curriculum and teachers' orientations (Nargund-Joshi et al., 2011). As Wahlström (2022) argues, teachers' approaches to the curriculum and their associated knowledge concepts are influenced by their perspectives, interpretations, beliefs, experiences, and social contexts. The proportional impact of teachers' emphasis on the curriculum on their orientations highlights the multifaceted nature of this relationship.

5.2.6 Interdisciplinary Connection

The teachers' effective integration of chemistry concepts with other science disciplines and their recognition of the suitability of the solutions topic for making these connections demonstrate their understanding of the interdisciplinary nature of science. Teacher 3's perspective on relating to other disciplines as an activity to develop higher-order thinking skills highlights the potential of interdisciplinary approaches to promote critical thinking and problem-solving skills.

5.2.7 Interconnectedness of Chemistry Concepts

The teachers' shared belief in the interconnectedness of chemistry concepts and their efforts to link previous topics with the current one demonstrate their understanding of the importance of building a comprehensive understanding of chemistry. The teachers' focus on comprehensive understanding indicates an awareness of how students' grasp of interconnected concepts can be assessed (Aydın, Friedrichsen, Boz & Hanuscin, 2014). Teacher 2's explicit questioning about lingering questions from the previous topic and Teacher 1 and Teacher 3's seamless integration of concepts from various chapters highlight different approaches to fostering these connections and promoting student engagement.

5.2.8 Real-world Applications and Interdisciplinary Examples

The teachers' use of interdisciplinary examples and their emphasis on showcasing the practical applications of chemistry in fields such as biology, engineering, and industry reflect their commitment to providing meaningful and relevant learning experiences for students. This approach aligns with research that emphasizes the importance of contextualized learning and the integration of real-world examples to enhance student understanding and foster curiosity in scientific inquiry (Gilbert, 2006).

In conclusion, the analysis of the teachers' knowledge of curriculum reveals the complex interplay between curriculum, PCK, and instructional decision-making. The teachers' awareness of curriculum reforms, their efforts to make vertical and horizontal connections, and their integration of interdisciplinary examples demonstrate their commitment to providing meaningful and relevant learning experiences for students. The varying degrees of emphasis placed on the curriculum by the teachers and its impact on their orientations highlight the multifaceted nature of this relationship, influenced by their perspectives, beliefs, experiences, and social contexts.

5.3 Knowledge of Instructional Strategies

Teachers did not use any subject specific strategies. The finding that teachers did not use any subject-specific strategies aligns with previous research by Aydemir (2014), Friedrichsen et al. (2007), and Yendi (2019). This suggests that the teachers may have limited PCK in terms of their knowledge of instructional strategies specific to teaching chemistry concepts. Subject-specific strategies, such as using particulate-level representations or concept mapping, can help students visualize and understand abstract chemical concepts (Treagust, Chittleborough, & Mamiala, 2003). The absence of these strategies may indicate a need for professional development to enhance teachers' PCK in this area.

None of the participants made any activity in laboratory. Actually Teacher 3 preferred to make experiment and she was the most enthusiastic about laboratory activities but she did not have a laboratory. Teacher 3, different from others, had M.S. degree on Chemistry, so she spends more time in laboratory than other participants. Her experiences may encourage her to make experiments. Teacher 1 and Teacher 2 were also aware of importance of laboratory activities; however, they do not prefer spend time in laboratory. Teacher 1 did not prefer laboratory activities not only this topic but also all other topics. Teacher 2 preferred to make demonstration experiments if he had adequate time. His aim for laboratory activities to motivate students and take their attentions. So, only Teacher 3 accepts laboratory activities as a learning tool. Teacher 1 preferred didactic scenario in card sorting activity his preferences about instructional strategy confirms this result.

The fact that none of the participants conducted laboratory activities highlights a potential gap in their PCK. Laboratory experiences are crucial for developing students' scientific skills, conceptual understanding, and appreciation for the nature of science (Hofstein & Lunetta, 2004). Teacher 3's enthusiasm for laboratory activities, likely influenced by her M.S. degree in Chemistry and extensive laboratory experience, demonstrates the impact of teacher background and beliefs on their instructional preferences (Magnusson, Krajcik, & Borko, 1999).

Teacher 1's avoidance of laboratory activities and Teacher 2's preference for demonstration experiments suggest a limited understanding of the role of inquiry-based learning in science education. Engaging students in hands-on investigations and problem-solving can promote deep learning and the development of scientific reasoning skills (Minner, Levy, & Century, 2010). These teachers may benefit from professional development focused on integrating meaningful laboratory experiences into their instruction.

The alignment between the teachers' instructional preferences (didactic vs. discovery scenarios) and their knowledge of assessment, as revealed through the card sorting activity, supports the interconnectedness of PCK components (Magnusson et al.,

1999). Teacher 1's preference for a didactic approach and Teacher 2 and 3's inclination towards discovery scenarios demonstrate the influence of their beliefs about teaching and learning on their instructional decisions.

5.4 Knowledge of Assessment

5.4.1 Use of Formative and Summative Assessment

All three participants' use of both formative and summative assessment methods aligns with the understanding that effective assessment should be continuous and multifaceted. As Heritage (2007) notes, PCK guides teachers in using assessment to monitor student learning and identify areas where additional support is needed. The teachers' use of written exams as summative assessments and probing questions during class as formative assessments demonstrates their knowledge of different assessment strategies and their purposes.

5.4.2 Assessment Results Informing Instructional Decisions

The participants' use of assessment results to shape their instructional decisions highlights the interplay between assessment and instruction in PCK development. As Park and Oliver (2008) emphasize, assessment plays a crucial role in developing PCK by informing the modification of instructional strategies. The teachers' ability to identify weaknesses in their instruction based on exam results demonstrates their reflective practice and adaptability, which are key components of PCK (Magnusson et al., 1999).

5.4.3 Variations in Exam Preparation Methods

Although the participants used identical exam formats, their different criteria for preparing exams (textbook, learning outcomes, and lesson plans) suggest the

influence of individual beliefs and orientations on assessment practices. This finding aligns with research by Aydın (2012) and Şen (2014), who highlighted the impact of contextual factors on assessment format. The teachers' PCK, shaped by their unique experiences and beliefs, guides their decision-making in creating assessments that align with their instructional goals and student needs (Magnusson et al., 1999).

5.4.4 Addressing Student Difficulties and Misconceptions

The teachers' use of probing questions to check for learning difficulties and misconceptions demonstrates their understanding of the central role of student thinking in assessment. As Henze, van Driel, and Verloop (2008) note, students' difficulties and misconceptions are key concepts for assessment in PCK. By actively seeking to uncover and address these challenges, the teachers are applying their PCK to support student learning and adapt their instruction accordingly.

5.4.5 Contextual Factors Influencing Assessment Practices

The finding that contextual factors, such as student characteristics and motivation, influenced the teachers' use of homework as an assessment tool highlights the situated nature of PCK. Teacher 2's use of homework as exercises for conscious students and Teacher 1's use of homework as a learning tool for less motivated students demonstrate their ability to adapt assessment practices to meet the specific needs of their learners. This flexibility and responsiveness are hallmarks of strong PCK (Magnusson et al., 1999).

In conclusion, the teachers' assessment practices, informed by their PCK, demonstrate a nuanced understanding of the role of assessment in supporting student learning and guiding instructional decisions. By employing a range of formative and summative methods, adapting to contextual factors, and addressing student difficulties and misconceptions, the teachers are applying their PCK to create effective and responsive learning environments. Ongoing reflection and professional

development can further strengthen their PCK and assessment practices, enabling them to continually refine their approach to supporting student learning in chemistry.

5.5 Orientation to Science Teaching

5.5.1 Varied Orientations to Science Teaching

The differences in the teachers' orientations to science teaching, as revealed through the card-sorting activity, highlight the individual nature of PCK. As Friedrichsen et al. (2011) note, teachers' orientations shape their PCK and influence their instructional strategies. The fact that all three participants hold different orientations for the same topic (solutions) underscores the idea that PCK is not a one-size-fits-all construct but rather a unique blend of knowledge, beliefs, and goals that each teacher brings to their practice (Kind, 2016; Shin & Song, 2021).

5.5.2 Context-Specific Nature of PCK

The finding that teachers' orientations may vary across different contexts, such as grade levels, student populations, or school settings, aligns with the understanding that PCK is context-specific (Kind, 2009). Teacher 3 did not focus on prior knowledge as other participants; however, he was aware of importance of prior knowledge. He just adapted instructional decisions for the context. The teachers' ability to adapt their orientations to meet the needs and demands of their particular teaching environment demonstrates the flexibility and responsiveness of their PCK. This adaptability is a hallmark of effective teaching and reflects the teachers' ability to tailor their instruction to the unique needs of their learners (Park & Oliver, 2008).

However, this result also raises questions about PCK development. How did these teachers develop such PCK? This aligns with ongoing research interest in PCK development trajectories (Kind, 2019). Additionally, the context-specific nature of

PCK (Carlson et al., 2019) suggests that these practices might vary across different chemistry topics, student populations, or educational settings.

5.5.3 Central and Peripheral Goals

The distinction between the teachers' central and peripheral goals, as highlighted by Friedrichsen and Dana (2005), provides insight into the hierarchical nature of PCK. While all three participants shared the central goal of preparing students for university entrance exams, their peripheral goals differed in terms of emphasis on higher-order thinking skills, discovery learning, and activity-driven instruction. The fact that Teacher 1 and Teacher 3 prioritized exam preparation over their peripheral goals due to time constraints reflects the impact of contextual factors on PCK (Jones & Carter, 2007; Ekiz Kıran, 2016).

5.5.4 Balancing Central and Peripheral Goals

The diversity between the teachers' central and peripheral goals does not necessarily indicate weak PCK. As Abell (2008) notes, teachers with strong PCK are able to navigate and balance their peripheral goals in light of contextual factors while still maintaining focus on their central goals. The participants' ability to adjust their goals and instructional approaches based on student needs, interests, and progress demonstrates their adaptability and responsiveness, which are key components of effective PCK (Park & Chen, 2012).

5.5.5 Integrating Central and Peripheral Goals

The challenge of balancing exam readiness with the promotion of critical thinking and inquiry skills highlights the complex nature of PCK. As Park and Chen (2012) note, teachers with robust PCK are able to elucidate the connections between their central and peripheral goals and design instruction that addresses both in an

integrated manner. By crafting coherent and meaningful learning experiences that balance exam preparation with the development of higher-order thinking skills, the teachers demonstrate their ability to apply their PCK in a holistic and student-centered manner.

Chan & Yung (2018) concluded that the integration of exam preparation with higher-order thinking skills development reflects current trends in PCK research that prioritize student-centered learning. Teacher 1's PCK is similar to this argument, but he could not focus on peripheral goals because of the time constraint. The alignment of PCK with different educational goals (such as exam preparation vs. critical thinking) demonstrates how PCK interacts with broader educational philosophies and policies. This interaction was also stated by Carlson et. al. (2019). The teachers' adjustment of their goals based on time constraints illustrates the dynamic and adaptive nature of PCK in practice. This issue also highlighted by Park & Oliver (2008).

In conclusion, the teachers' varied orientations to science teaching, context-specific PCK, and balancing of central and peripheral goals reflect the complex and dynamic nature of PCK. By adapting their instruction to meet the unique needs of their learners and navigating contextual factors while still maintaining focus on their central goals, the teachers demonstrate the flexibility and responsiveness of their PCK. Ongoing reflection and professional development can further strengthen their ability to integrate their central and peripheral goals and create meaningful learning experiences that prepare students for both exams and real-world application of their knowledge and skills.

5.6 Implications

5.6.1 Providing Ongoing Professional Development Focused on PCK

In-service teachers should have access to high-quality professional development opportunities that focus on enhancing their PCK. These professional development programs should be sustained, job-embedded, and responsive to teachers' specific needs and contexts. They should provide opportunities for teachers to deepen their subject matter knowledge, explore effective instructional strategies, analyze student work, and collaborate with colleagues. Professional development that emphasizes reflective practice and the integration of PCK components can help teachers continually refine their practice and adapt to the evolving needs of their students.

5.6.2 Fostering a Culture of Collaboration and Shared Expertise

Schools and districts should foster a culture of collaboration and shared expertise among science teachers. Creating professional learning communities where teachers can regularly meet to discuss their practice, share resources, and analyze student learning can help them collectively develop their PCK. Encouraging mentoring relationships between experienced and novice teachers can also facilitate the transfer of PCK and support the growth of all teachers. Collaborative efforts to design and implement curriculum, assessments, and instructional strategies can lead to more coherent and effective science instruction across classrooms and grade levels.

5.6.3 Aligning Curriculum, Assessment and Instruction with PCK Development

Educational policymakers and curriculum developers should consider the importance of PCK when designing science curriculum, assessments, and instructional resources. Aligning these elements with research-based practices that

support PCK development can help create a more coherent and supportive environment for science teaching and learning. Curriculum materials that emphasize conceptual understanding, inquiry-based learning, and real-world applications can provide a strong foundation for teachers to develop and apply their PCK. Assessments that focus on deeper learning and provide opportunities for teachers to gather evidence of student understanding can inform their instructional decision-making and support their ongoing PCK development.

5.6.4 Recognizing and Supporting the Complex and Contextual Nature of PCK

Educational leaders and policymakers should recognize that PCK is a complex and contextual construct that requires ongoing support and development. They should provide teachers with the time, resources, and autonomy needed to engage in reflective practice, collaborate with colleagues, and adapt their instruction to the unique needs of their students and school contexts. Recognizing the value of teachers' professional judgment and expertise can create a more supportive environment for PCK development and effective science teaching.

5.6.5 Conducting Further Research on PCK and its Impact on Student Learning

Researchers should continue to investigate the nature, development, and impact of PCK in science education. Further studies that examine the relationship between teachers' PCK and student learning outcomes, as well as the effectiveness of different approaches to PCK development, can inform educational policy and practice. Research that explores the role of contextual factors, such as school culture, student demographics, and curriculum standards, on teachers' PCK can also provide valuable insights into the complex realities of science teaching.

By considering these implications and taking action to support the development and application of strong PCK among science teachers, educational stakeholders can create a more effective and equitable system of science education. Ultimately, investing in teachers' PCK is an investment in the quality of science learning experiences for all students, preparing them for success in an increasingly complex and scientifically-driven world.



REFERENCES

- Abell, S. K. (2007). Research on science teacher knowledge. In S. K. Abell, & N. G. Lederman (Eds.), *Handbook of research on science education* (pp.1105-1151). Lawrence Erlbaum Associates.
- Abell, S. K. (2008). Twenty years later: Does pedagogical content knowledge remain a useful idea? *International Journal of Science Education*, 30(10), 1405-1416.
- Aydemir, M. (2014). *The Investigation of Pedagogical Content Knowledge of Teachers:The Case of Teaching Genetics*. Unpublished Doctoral Thesis. Middle East Technical University, Ankara.
- Aydin, S., & Boz, Y. (2013). The nature of integration among PCK components: A case study of two experienced chemistry teachers. *Chemistry Education Research and Practice*, 14(4), 615-624.
- Aydin, S., Friedrichsen, P. M., Boz, Y., & Hanuscin, D. L. (2014). Examination of the topic-specific nature of pedagogical content knowledge in teaching electrochemical cells and nuclear reactions. *Chemistry Education Research and Practice*, 15(4), 658-674.
- Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, 59(5), 389-407.
- Berliner, D. C. (2001). Learning about and learning from expert teachers. *International Journal of Educational Research*, 35(5), 463-482
- Berry, A., Friedrichsen, P. J., & Loughran, J. (Eds.). (2015). *Re-examining pedagogical content knowledge in science education* (Vol. 395). New York: Routledge.

- Bogdan R. C. & Biklen, S. K. (1998). Qualitative research for education: An introduction to theory and methods (3rd ed.). Allyn and Bacon, Boston.
- Bucat, R. (2004). Pedagogical content knowledge as a way forward: Applied research in chemistry education. *Chemistry Education Research and Practice*, 5(3), 215-228.
- Carlsen, W. (1999). Domains of teacher knowledge. In *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 133-144). Springer Netherlands.
- Carlson, J., Daehler, K. R., Alonzo, A. C., Barendsen, E., Berry, A., Borowski, A., & Wilson, C. D. (2019). The refined consensus model of pedagogical content knowledge in science education. *Repositioning pedagogical content knowledge in teachers' knowledge for teaching science*, 77-94.
- Chan, K. K. H., & Yung, B. H. W. (2018). Developing pedagogical content knowledge for teaching a new topic: More than teaching experience and subject matter knowledge. *Research in Science Education*, 48, 233-265.
- Cochran, K. F., King, R. A., & DeRuiter, J. A. (1991). *Pedagogical Content Knowledge: A Tentative Model for Teacher Preparation*. East Lansing, MI: National Center for Research on Teacher Learning. (ERIC Document Reproduction Service No. ED340683)
- Çetin-Dindar, A., Boz, Y., Sonmez, D. Y., & Celep, N. D. (2018). Development of pre-service chemistry teachers' technological pedagogical content knowledge. *Chemistry Education Research and Practice*, 19(1), 167-183.
- Demirdöğen, B. (2016). Interaction between science teaching orientation and pedagogical content knowledge components. *Journal of Science Teacher Education*, 27, 495-532.
- Drechsler, M., & Van Driel, J. (2008). Experienced teachers' pedagogical content knowledge of teaching acid-base chemistry. *Research in science education*, 38, 611-631.

- Ekiz Kiran, B. (2016). *Interaction between experienced chemistry teachers' science teaching orientations and other components of pedagogical content knowledge in mixtures*. Doctoral Dissertation, Middle East Technical University Graduate School of Natural and Applied Sciences, Ankara.
- Ekiz-Kiran, B., Boz, Y., & Oztay, E. S. (2021). Development of preservice teachers' pedagogical content knowledge through a PCK-based school experience course. *Chemistry Education Research and Practice*, 22(2), 415-430.
- Feierabend, T., Jokmin, S., & Eilks, I. (2011). Chemistry teachers' views on teaching 'climate change'-an interview case study from research-oriented learning in teacher education. *Chemistry Education Research and Practice*, 12(1), 85-91.
- Friedrichsen, P., & Dana, T. (2005). A substantive-level theory of highly regarded secondary biology teachers' science teaching orientations. *Journal of Research in Science Teaching*, 42, 218-244
- Friedrichsen, P., Van Driel, J. H., & Abell, S. K. (2011). Taking a closer look at science teaching orientations. *Science Education*, 358-376
- Geddis, A. N., Onslow, B., Beynon, C., & Oesch, J. (1993). Transforming content knowledge: Learning to teach about isotopes. *Science Education*, 77(6), 575-591.
- Gess-Newsome, J. (1999). Pedagogical content knowledge: An introduction and orientation. In *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 3-17). Springer Netherlands.
- Gess-Newsome, J (2015). A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK Summit. In *Re-examining pedagogical content knowledge in science education* (pp. 28-42). Routledge.

- Grossman, P. (1990). *The making of a teacher*. Teachers College Press
- Henze, I., van Driel, J. H., & Verloop, N. (2008). Development of experienced science teachers' pedagogical content knowledge of models of the solar system and the universe'. *International Journal of Science Education*, 30(10),1321-1342.
- Hofer, S. I., Schumacher, R., Rubin, H., and Stern, E. (2018). Enhancing physics learning with cognitively activating instruction: a quasi-experimental classroom intervention study. *J. Educ. Psychol.* 110, 1175–1191.
- Hume, A., Cooper, R., & Borowski, A. (Eds.). (2019). *Repositioning pedagogical content knowledge in teachers' knowledge for teaching science*. Singapore: Springer Singapore.
- Janesick, V. J. (2007). Peer debriefing. *The Blackwell encyclopedia of sociology*.
- Jones, M.G., & Carter, G. (2007). Science teacher attitudes and beliefs. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research in science education* (pp. 1067-1105). New York: Routledge.
- Kind, V. (2009). Pedagogical content knowledge in science education: perspectives and potential for progress. *Studies in science education*, 45(2), 169-204.
- Kind, V., & Chan, K. K. (2019). Resolving the amalgam: connecting pedagogical content knowledge, content knowledge and pedagogical knowledge. *International Journal of Science Education*, 41(7), 964-978.
- Loughran, J. J., Berry, A., & Mulhall, P. (2006). *Understanding and developing science teachers' pedagogical content knowledge*. Brill.
- Luft, J. A., & Roehrig, G. H. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *The Electronic Journal for Research in Science & Mathematics Education*.

- Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In Examining pedagogical content knowledge: *The construct and its implications for science education* (pp. 95-132). Dordrecht: Springer Netherlands.
- Mahler, D., Großschedl, J., & Harms, U. (2017). Using doubly latent multilevel analysis to elucidate relationships between science teachers' professional knowledge and students' performance. *International Journal of Science Education*, 39(2), 213–237.
- Marks, R. (1990). Pedagogical content knowledge: From a mathematical case to a modified conception. *Journal of teacher education*, 41(3), 3-11.
- Mavhunga, E. (2020). Revealing the structural complexity of component interactions of topic-specific PCK when planning to teach. *Research in Science Education*, 50(3), 965-986.
- Merriam, S. B. (1998). *Qualitative Research and Case Study Applications in Education. Revised and expanded from "Case Study Research in Education."*. Jossey-Bass Publishers, 350 Sansome St, San Francisco, U.S.A.
- Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.
- Morrison, A. D., & Luttenegger, K. C. (2015). Measuring pedagogical content knowledge using multiple points of data. *The Qualitative Report*, 20(6), 804-816.
- Nargund-Joshi, V., Park Rogers, M., & Bhagwate, D. (2019). A Comparative Case Study of Primary Science Teachers' Beliefs and Orientations. Science Education in India: *Philosophical, Historical, and Contemporary Conversations*, 91-112.

- Öztürk Ferah, H. (2022). *Investigation of Physics Teachers and Pre-Service Physics Teacher's Pedagogical Content Knowledge on Electricity Based on Proportional Reasoning* Doctoral Dissertation, Hacettepe University
- Patton, M. Q. (2002). *Qualitative research & evaluation methods*. Sage.
- Shannon, J. C. (2006). *How is PCK embodied in the instructional decisions teachers' make while teaching chemical equilibrium?* Doctoral Dissertation, University of Washington, USA
- Shin, C., & Song, J. (2021). A Study on Science Teaching Orientation and PCK Components as They Appeared in Science Lessons by an Experienced Elementary Teacher: Focusing on 'Motion of Objects' and 'Light and Lens'. *Journal of The Korean Association for Science Education*, 41(2), 155-169.
- Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational researcher*, 15(2), 4-14.
- Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard educational review*, 57(1), 1-23.
- Tamir, P. (1988). Subject matter and related pedagogical knowledge in teacher education. *Teaching and teacher education*, 4(2), 99-110.
- Tepner, O., & Dollny, S. (2013, September). Measuring chemistry teachers' content knowledge: Is it correlated to pedagogical content knowledge? *In Topics and Trends in Current Science Education: 9th ESERA Conference Selected Contributions* (pp. 243-254). Dordrecht: Springer Netherlands.
- Tomlinson, C. A., Brighton, C., Hertberg, H., Callahan, C. M., Moon, T. R., Brimijoin, K., Conover, L.A. & Reynolds, T. (2003). Differentiating instruction in response to student readiness, interest, and learning profile in academically diverse classrooms. *Journal for the Education of the Gifted*, 27(2-3), 119-145.

Tytler, R. (2007). Re-imagining science education: Engaging students in science for Australia's future. *Teaching Science*, 53(4), 14-17.

Van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 38(2), 137-158.

Van Driel, J. H., Verloop, N., & De Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 35(6), 673-695.

Wahlström, N. (2023). Curriculum policy, teaching, and knowledge orientations. *Teachers and Teaching*, 29(3), 259-275.

APPENDICES

A. Demographic Information

Age

Education level

Experience (Years / school type)

Experience in different curriculum

B. Semi-Constructed Interview Protocol

- Öğrenci Bilgisi
 - Öğrenciler kimya dersi ile ilgili zorluk yaşıyorlar mı?
 - Öğrenciler çözeltiler konusunda zorluk yaşıyorlar mı?
 - Çözeltiler konusunu öğrenmenin avantajları nelerdir?
 - Konuyu öğrenmek için ön bilginin önemi nedir? Bu konuyla ilgili özel bir çabanız var mı?
 - Kavram yanılgılarını / yanlış anlamaları tespit etmek için / üstesinden gelmek için neler yapıyorsunuz?
- Müfredat Bilgisi
 - Müfredata hakim misiniz?
 - Müfredatın zayıf ve güçlü yanları nelerdir?
 - Müfredattaki değişiklikler hakkında ne düşünüyorsunuz?
 - Müfredata bağlı kalır mısınız?
- Öğretim Yöntemi Bilgisi
 - Kullandığınız öğretim yöntemini neleri göz önüne alarak seçiyorsunuz?
 - Konudan konuya farklılık gösteriyor mu?
 - Çözeltiler konusunda önemli kavramlar nelerdir?

- Kullandığınız yöntemin etkinliğini sorguladınız mı?
- Meslek yaşantınız süresince öğretim yöntemleriniz değişiklik gösterdi mi?
- Ölçme bilgisi
 - Neyi ölçeceğinize nasıl karar verirsiniz?
 - Nasıl ölçersiniz?
 - Niye ölçersiniz?
 - Ölçme yönteminiz konudan konuya değişiklik gösterir mi?
 - Ölçme sonuçları nelere etki eder?

C. PCK Coding Table

Codes	Sub-Codes	Definition
Knowledge of Learner	Pre-requisite knowledge	The knowledge needed for learners in order to learn particular scientific topics
	Student Difficulties	The knowledge about science concepts that learners find difficult to learn
	Misconceptions	learners' ideas different from scientifically accepted description
Knowledge of Curriculum	Curricular saliency	Emphasis on specific concepts
	Altering curriculum	Modification on curriculum
	Vertical curriculum	Teachers' knowledge of curriculum about relations to other topics in the different grade
	Horizontal curriculum	Teachers' knowledge of curriculum about

		relations to other topics in the same grade
	Relation to other disciplines	Making connections with other disciplines
Knowledge of Instructional Strategies	Subject Specific Strategies	The strategies used for teaching science which are particular to only teaching chemistry
	Topic Specific Strategies	The strategies used for teaching science which are particular to only teaching the topic
Knowledge of Assessment	Methods of assessment	How to assess student learning as related to stated goals
	Dimension to science learning	What to assess student learning as related to stated goals
Science Teaching Orientations	Process	Help students develop the “science process skills.”
	Academic rigor	Represent a particular body of knowledge
	Didactic	Transmit the facts of science
	Conceptual change	Facilitate the development of scientific knowledge by confronting students with contexts to explain that challenge their naive conceptions
	Activity driven	Hands-on experiences for students
	Discovery	Students discover the concepts by activities

Project-based science	Students investigate solutions for a problem
Inquiry	Represent science as inquiry
Guided inquiry	Teacher guides for inquiry

D. Card Sorting Activity

- Öğretmen yeni bir bilgi elde edebilmek için bilim adamlarının kullandığı düşünme süreçleri hakkında öğrencilerine bilgi verir. Öğrencilere çözücü çözünen etkileşimlerini öğretmenin etkili bir yolu, öğrencilerin düşünme sürecini ve becerilerini geliştirebilecekleri uygun ortamlar oluşturmaktır. (Süreç)
- Derişim birimlerini öğretmenin etkili bir yolu, öğrencileri zor soru ve aktivitelerle zorlamaktır. Laboratuvar çalışmaları ve gösteri deneyleri, belirli kavramlar ve olgular arasındaki ilişkinin gösterilmesi yoluyla, fen kavramlarını doğrulamak için kullanılır. (Akademik disiplin)
- Koligatif özellikleri öğretmenin etkili bir yolu; öğretmenin genellikle düz anlatım veya tartışma yoluyla bilgiyi sunması ve öğrencilerin bilimsel gerçekleri bilip bilmediğini anlamak için sorular sormaktır. (Didaktik)
- Çözünürlüğe etki eden faktörleri öğretmenin etkili bir yolu öğrencilerin konuyla ilgili ön bilgilerini ortaya çıkarmak, alternatif açıklamalarını belirlemek, bu alternatif açıklamaları kullanarak öğrencilerin zihninde bir çatışma yaratmak ve bu zihinsel çatışmayı tartışmalar yoluyla çözmektir. (Kavramsal değişim)

- Özütlemeyi (ekstraksiyon) öğretmenin etkili bir yolu, öğrencilere doğrulama veya keşfetme için kullanılan el becerisine dayalı aktiviteler yaptırmaktır. (Aktivite temelli)
- İyon-dipol etkileşimlerini öğretmenin etkili bir yolu, öğrencilere farklı maddelerin sudaki çözünürlüklerini keşfedebilecekleri bir deney tasarlatmaktır. (Keşfettirici)
- Çözücü çözünen etkileşimlerini öğretmenin etkili bir yolu, öğrencilere dipol-dipol etkileşimleri, iyon-dipol etkileşimleri ve dipol-indüklenmiş dipol etkileşimleri ile ilgili bir proje hazırlatmaktır. (Proje tabanlı)
- Sıcaklığın çözünürlüğe etkisini öğretmenin etkili bir yolu, öğrencilerin konu ile ilgili problemi keşfetmeleri ve tanımlamaları, araştırma yapmaları, çıkarımlar yapmaları, çıkarımlarından elde ettikleri sonuçları değerlendirmelerine izin vermektir. (Sorgulayıcı araştırma)
- Çözünürlüğün sıcaklık, basınç ve çözücü ile değişme eğilimini modern ayırma yöntemleriyle ilişkilendirmeyi öğretmenin etkili bir yolu, konu ile ilgili bir problemi tanımlama, izlenecek yollara karar verme, açıklamaları test etme, verilerinin kullanılabilirliği ile güvenilirliğini ve sonuçlarının yeterliliğini değerlendirme süreçlerine; öğretmen ve öğrencilerin katıldığı bir etkinlik yapmaktır. (Rehberli sorgulayıcı araştırma)
- Kart grupta aktivitesi öncesinde öğretmene yöneltilen sorular:
 - Sizin bakış açınızdan kimya eğitiminin amaçları nelerdir?
 - Bu amaçları nasıl belirlediniz? Bu amaçları belirlerken size yardımcı olan / sizi etkileyen unsurlar nelerdir?
- Kart grupta aktivitesi sonrası öğretmene yöneltilen sorular
 - Bu senaryo sizin öğretim yönteminizle benzerlik gösteriyor mu?
 - Amaçlarınıza uygun mu? Amaçlarınıza ulaşmanızda yardımcı olur mu?

- Seçtiğiniz senaryolar haricinde başka bir strateji uyguluyor musunuz / uygulamak ister misiniz?
- Olumlu yönde seçtiğiniz senaryoların ortak yönleri nelerdir?
- Kararsız kaldığınız senaryoları tercih etmemenizin nedenleri nelerdir?
- Kararsız kaldığınız senaryolarda herhangi bir değişiklik yapabilseydiniz tercihiniz olumlu yönde değişir miydi?
- Kararsız kaldığınız senaryoların ortak yönleri nelerdir?
- Tercih etmediğiniz senaryoların sizin öğretim yaklaşımınızı yansıtmayan yönleri nelerdir?
- Tercih etmediğiniz senaryolarda değişiklik yapma şansınız olsaydı ne gibi bir değişiklik yapardınız? Bu değişiklik fikrinizi nasıl etkilerdi?
- Tercih etmediğiniz senaryoların ortak yönleri nelerdir?

E. Permission for Data Collection

Evrak Tarih ve Sayısı: 23/02/2016-4877

 T.C.
KDZ.EREĞLİ KAYMAKAMLIĞI
İlçe Milli Eğitim Müdürlüğü

Sayı : 88136896-100-E.2030870 22.02.2016
Konu : 2015-2016 Öğretim Bahar Yılı "Doktora Tez Çalışma İzni."

BÜLENT ECEVİT ÜNİVERSİTESİ EREĞLİ EĞİTİM FAKÜLTESİ DEKANLIĞINA

İlgi: a) 11/02/2016 tarihli ve 65719904.902.02/2222 sayılı yazılarınız.
b) Kaymakamlık Makamının 19/02/2016 tarihli ve 88136896-100-E.1970654 sayılı onayları.

İlgi (a) yazınız gereği alınan; Fakülteniz Araştırma Görevlisi Cem BÜYÜKEKŞİ' ye ait 2015-2016 Öğretim Bahar Yılı "Doktora Tez Çalışma İzni" ile ilgili Kaymakamlık Makamının İlgi (b) onayları ekte gönderilmektedir.

Bilgilerinize arz ederim.

Numan KORKMAZ
İlçe Milli Eğitim Müdürü

EK:
Onay (1 sayfa)

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FOREIGN LANGUAGES

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PUBLICATIONS

1. Büyükekşi C., Yavuz S. (2021). Fen bilgisi ve Sınıf öğretmenliği öğrencilerinin ısı ve sıcaklık konularındaki kimya bilgilerini günlük hayattaki olaylarla ilişkilendirebilme düzeyleri. *Türkiye Kimya Derneği Dergisi Kısım C: Kimya Eğitimi*, 6(2), 285-302.
2. Yavuz, S., Büyükekşi, C., & Çolakoğlu, Ö. M. (2020). Effect Of 3D Applications In Organic Chemistry Lesson On Students' Spatial Ability. *Online Science Education Journal*, 5(1), 1-8.
3. Büyükekşi, C., Gerçek, Z., & Yavuz, S. (2018). İlköğretim öğrencilerinin kimya algılarının metaforlar aracılığıyla incelenmesi. *Karaelmas Eğitim Bilimleri Dergisi*, 6(2), 269-276.

4. Yavuz, S., & Büyükekşi, C. (2018). Molekül Modeli Uzamsal Yetenek Testi Geliştirme Çalışması. *Türkiye Kimya Derneği Dergisi Kısım C: Kimya Eğitimi*, 3(2), 59-76.
5. Büyükekşi C., Aydın Şengüleç Ö., Bahçivan E., Yavuz S. (2017). Fen ve Teknoloji Öğretmen Adaylarının Argümantasyon Yoluyla Kimyadaki Kavramsal Anlamalarının Geliştirilmesi Üzerine DeneySEL Bir Çalışma. *Karaelmas Eğitim Bilimleri Dergisi*, 5(2), 224-235.)
6. Büyükekşi C., Yavuz S. (2016). Fen Bilgisi Öğretmenliği Öğrencilerinin Kimya Algılarının İncelenmesi. *Türkiye Kimya Derneği Dergisi, Kısım C: Kimya Eğitimi*, 1(1), 107-118.
7. Yavuz S., Büyükekşi C. (2016). Günlük Yaşamdaki Kimya Kavram Yanılgılarının Atasözleri ile Tespit Edilmesi. *Karaelmas Fen ve Mühendislik Dergisi*, 6(1), 182-186.
8. Yavuz S., Büyükekşi C. (2015). Tepkime Hızı Konusundaki Öğrenci Kavram Haritalarının Değerlendirilmesi. *Karaelmas Eğitim Bilimleri Dergisi*, 3(2), 126-132.
9. Yavuz S., Büyükekşi C., Işık Büyükekşi S.e (2014). Bilim Şenliğinin Bilimsel İnanışlar Üzerine Etkisi. *Karaelmas Eğitim Bilimleri Dergisi*, 2(2), 168-174.)
10. Yavuz, S., & Büyükekşi, C. (2011). Kavram Karikatürlerinin Isı-Sıcaklık Kavramlarının Öğretiminde Kullanılması. *Karaelmas Fen ve Mühendislik Dergisi*, 1(2), 25-30.