EXAMINATION OF TOPIC-SPECIFIC NATURE OF PEDAGOGICAL CONTENT KNOWLEDGE: A CASE OF SCIENCE TEACHER OF GIFTED STUDENTS

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ABSTRACT

EXAMINATION OF TOPIC-SPECIFIC NATURE OF PEDAGOGICAL CONTENT KNOWLEDGE: A CASE OF SCIENCE TEACHER OF GIFTED STUDENTS

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The aims of this study were to investigate the topic-specific pedagogical content knowledge (PCK) of a science teacher working with gifted students, and to investigate the interaction of the teacher's PCK components. Single case study methodology in qualitative nature was utilized, and the case was comprised of a middle school science teacher who worked in a private school including 7^{th} grade gifted students. Three physics topics; work and energy, simple machines, and friction force were selected to gain rich information about the participant teacher's teaching through in a long term observation. The data were collected through card-sorting activities, CoRe (Content Representation), semi-structured interviews, classroom observations, and field notes.

The study results showed that the teacher had multiple science teaching orientations about science teaching and learning. She had also strong knowledge of curriculum and used science curriculum effectively while designing and applying related topics. As regarding knowledge of learner, her teaching was affected by characteristics of gifted students leading the teacher to design and apply enrichment activities. Moreover, topic-specific instructional strategies were often employed while teaching related topics. The teacher's knowledge of assessment included informal strategies such as questioning and monitoring, and formal assessment such as quizzes, multiple choices tests, and exams at the end of the unit. Finally, as regarding the interaction of teacher's PCK components, the planning and practicing maps had different characteristics and they had topic-specific in nature. The teacher knowledge about the characteristics of gifted students and enrichment curriculum shaped and influenced her planning and teaching related topics.

Keywords: Pedagogical content knowledge, interaction of PCK components, middle school science teacher, gifted students, and physics topics.

ÖZ

BİR FEN BİLİMLERİ ÖĞRETMENİNİN PEDAGOJİK ALAN BİLGİSİNİN KONUYA ÖZGÜ DOĞASININ İNCELENMESİ; ÜSTÜN YETENEKLİ ÖĞRENCİLERİN ÖĞRETMENİNİN DURUMU

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Bu çalışmanın amaçları, üstün yetenekli öğrencilerin fen bilimlileri öğretmenin pedagojik alan bilgisinin (PAB) konuya özgü doğasını tüm bileşenleriyle incelemek ve öğretmenin kullandığı PAB bileşenlerinin etkileşimlerini incelemektir. Çalışmada tekli durum (case study) çalışması kullanılmıştır. Bu kapsamda çalışmaya, özel bir okulda ortaokul 7. sınıf üstün yetenekli öğrencilerin öğretmeni olarak görev yapan bir fen bilimleri öğretmeni katılmıştır. Bu öğretmenin pedagojisi hakkında bilgi elde etmek için onun, üç fizik konusundaki "iş-enerji, basit makineler ve sürtünme kuvveti" öğretimi gözlemlenmiştir. Bu gözlem ile bağlantılı olarak çalışmanın verileri kart gruplama aktiviteleri, içerik gösterimi (CoRe), yarı yapılandırılmış görüşmeler, sınıf gözlemleri ve gözlem notları ile toplanmıştır.

Bu verilerden elde edilen sonuçlar, öğretmenin çoklu fen öğretimi oryantasyonuna ve gelişmiş bir ortaokul program bilgisine sahip olduğunu göstermiştir. Buna göre öğretmen, ilgili programı hem planlama hem de konuların öğretimi sırasında etkili bir şekilde kullanmaktadır. Öğretmen, öğrenci bilgisi açısından ele alındığında ise üstün yetenekli öğrencilerin karakteristik özelliklerinden dolayı zenginleştirilmiş etkinliklere ihtiyaç duydukları ve bu ihtiyaçların öğretmenin hem planlama hem de öğretimini etkilediği görülmüştür. Bu bulgulara ek olarak, öğretmen tarafından konuya özgü öğretim stratejilerine sıklıkla başvurulmakla birlikte soru-cevap ve gözlemler gibi informal; dönem sonu sınavları, açık uçlu ve çoktan seçmeli testler gibi formal değerlendirme yöntemleri kullanılmaktadır. Son olarak, öğretmenin pedagojik alan bilgisi bileşenlerinin etkileşimi incelendiğinde, hem planlama hem de uygulama haritalarının birbirinden farklı ve konu tabanlı bir karakteristiğe sahip olduğu görülmüştür. Çalışmanın bulguları genel olarak değerlendirildiğinde, öğretmenin ilgili konuları hem planlama hem de uygulama bilgilerinin, üstün yetenekli öğrencilerin karakteristik özelliklerinden etkilendiği ve bu özelliklerin bilgisi ile zenginleştirilmiş aktiviteler bilgisinin, öğretmenin öğretimini şekillendirdiği ifade edilebilir.

Anahtar Kelimeler: Pedagojik alan bilgisi, pedagojik alan bilgisi bileşenlerinin etkileşimi, fizik konuları, üstün yetenekli öğrenciler ve fen bilimleri öğretmeni

To my wife, Şeyma EŞKİ ÇAYLAK, for your love, support, and trust

&

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LIST OF ABBREVIATIONS

PCK	Pedagogical Content Knowledge
SMK	Subject Matter Knowledge
PK	Pedagogical Knowledge
MNE	Ministry of National Education
CoRe	Content Representation
NOS	Nature of Science
STSE	Science, Technology, Society, and Environment
STO	Science Teaching Orientation
KoC	Knowledge of Curriculum
KoL	Knowledge of Learner
KoIS	Knowledge of Instructional Strategies
KoA	Knowledge of Assessment

CHAPTER 1

INTRODUCTION

Physics topics and concepts are considered by both teachers and students as abstract and difficult construct for teaching and learning (Ahtee & Johnston, 2006; Hammer, 1996). Therefore, teaching and learning of any physics concepts require large number of attempts and efforts to overcome the learning difficulties. For someone from the outside of school context, this is not very clear to understand and imagine these challenges and efforts because teaching includes complex process. Moreover, effective and meaningful teaching arises from multiple resources (Shulman, 1987). For instance, “work” concept in the unit of “force and movement” in the middle school level means to move an object in the direction of applied force. In other words, in order to create a physical work, an object must be subjected by a force and the object should be displaced in the same direction with force. The definition might be also summarized in the formula of Work = Force x Distance. In this respect, if teaching appears only to saying the definition of work concept, it would be enough to saying above formula for students or getting the students take notes of the definition including only two or three sentences. By doing so, this pedagogical strategy might be considered a teaching and learning of “work” concept for someone from outside of school context. However, it is not enough for effective teaching or meaningful learning due to the fact that there are many things to be considered by the teachers to make students meaningfully learn. Those things include subject matter knowledge (SMK), general pedagogical knowledge (PK), or contextual factors, which materials the teacher used, students’ knowledge and abilities, etc.

With above example in mind, teaching is complex process and it enables teachers to have knowledge of what to know and how to know (Shulman, 1987). Then teachers start to think their plan including such questions; what are our goal and purposes to teach the concept?, what are the curriculum objectives and materials?, what is the student's knowledge and abilities such as prior knowledge, misconceptions, or learning difficulties?, which instructional strategies are more appropriate for both students and the concept?, and how can we assess the students' performance? (Magnusson, Klajcik, & Borko, 1999). This is only planning stage, and when looking at practicing part, teachers face to other challenges and difficulties. In order to handle these difficulties in classroom context, teachers require specific knowledge base which is different from SMK and general PK.

Along this line, a new type of knowledge has been defined as pedagogical content knowledge (PCK). A large number of researches in teacher education have focused on PCK as important teacher knowledge (Abel, 2007; Grossman, 1990; Loughran, Berry, & Mulhall, 2006; Magnusson et al., 1999). In teaching process, teachers present particular concepts, skills, abilities, attitudes, or performance skills by using specific lecturing, performing, demonstrating, or other type of presentations (Shulman, 1987). In this process PCK plays a crucial role to transfer SMK to teaching practice, and PCK is defined as "the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations-in a word, the ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, p. 9). It has been used by many researchers in different context such as, pre-service versus expert teachers, elementary versus secondary teachers, or topic-specific versus subject-specific. Its popularity has been still continued because each topic or content is still utilized as a missing paradigm in the PCK research (Abell, 2008). It is agreed that PCK studies have not been still enough (Abell, 2008; Loughran, Mulhall, & Berry, 2004; van Driel, Verloop, & De Vos, 1998) to complete the puzzle, if each PCK study is accepted a part of this puzzle.

Shulman (1987) clarified the knowledge bases and introduced first PCK. Then, following researchers focused on the knowledge bases and extended Shulman's definition of PCK. Grossman (1990) studied with Shulman's model of knowledge bases and she separated pedagogical knowledge from PCK. She also attributed the component of orientation as separated knowledge teachers need to know, and she defined teaching orientation as "conceptions of purposes for teaching subject matter" (p. 5). Tamir (1988) organized the knowledge bases such as SMK, general pedagogical knowledge, PCK in order to create a useful framework for researchers, and added knowledge of assessment components to the framework. Mark (1990) was another scholar to support PCK model as integrating new component of "media". Furthermore, there were some other scholars to reconsider PCK under different views such as PCK was analyzed under three groups; general PCK, domain-specific PCK, and topic specific PCK (Veal & MaKinster, 1999), and integrative and transformative PCK models (Gess-Newsome, 1999).

Until above studies, researchers focused on general teacher education and knowledge bases. Magnusson et al. (1999) generated a PCK model for science teachers. They defined PCK as follows;

> Pedagogical content knowledge is a teacher understanding of how to help students understand specific subject matter. It includes knowledge of how particular subject matter topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction (p. 96).

Moreover, Magnusson et al. (1999) explained PCK under five components; science teaching orientation (STO), knowledge of curriculum (KoC), knowledge of learner (KoL), knowledge of instructional strategies (KoIS), and knowledge of assessment (KoA). This model has provided science teachers education literature with valuable information about topic specific in nature. Also this PCK model has been the most used by scholars as a conceptual and analytical framework (Abell, 2007; Gess-Newsome, 2015). After Magnusson et al.'s (1999) conceptualization, PCK literature has been extended and still continued the development by other researchers by adding some components (Park & Oliver, 2008) or revising the teachers' knowledge bases models (Gess-Newsome, 2015).

To make science teacher's PCK more clear and understandable, researcher have agreed to give more attention to the interactions of PCK components (Abell, 2008; Magnusson et al., 1999; Park & Chan, 2012). While teaching any science concept, teachers use specific components in a combination to present specific knowledge and abilities. In other words, the components act coherently (Loughran et al., 2006) through utilizing that one component informs to others. Moreover, the interaction among PCK components can explain more clearly the teachers' teaching behaviors. Therefore, investigating the interaction components is more important and it is expected to provide science teacher education with valuable experience and knowledge (Park & Oliver, 2008).

To sum up, teacher's PCK has been investigated science teacher education literature since 1986 and it has valuable or significant knowledge and experience in order to find out the answers of question "What kinds of knowledge do teachers need in order to be effective in their classrooms?" (Tamir, 1988, p.99). This question has been utilized for general and science teachers to enhance their abilities or knowledge. However, there is an ignoring part of teacher education for gifted students (Shaughnessy & Sak, 2015). Gifted learners have some special abilities in academic domain and present a special performance especially intellectual functioning different from their peers (Gagne, 2004; Gilman, 2008; Taber, 2007).

Different than the other students, gifted learners have some particular characteristics observed in science classes. Gifted students interrogate and question new information (Stott & Hobden, 2016), ask challenging, unusual, and insightful questions (Miller, 2009; Park & Oliver, 2009), learn science concepts easier and more quickly than peers (Gilman, 2008; Joffe, 2001; Manning, 2006; Miller, 2009; Park & Oliver, 2009; Taber, 2007), have perfectionist traits to complete any works (Joffe, 2001; Park & Oliver, 2009), dislike routine, notetaking, and homework (Joffe, 2001; Park & Oliver, 2009; Samardzija & Peterson, 2015), enjoy participating complex, discovery, students-centered, self-discovery learning environment (Friddyment, 2014; Joffe, 2001; Miller, 2009; Samardzija & Peterson, 2015; Taber, 2007), and transfer effectively obtained knowledge and implement it to new conditions (Manning, 2006; Miller, 2009; Stott & Hobden, 2016).

By taking into account above characteristics, these special abilities lead some requirements to be handled by teachers in classroom context. In other words, these characteristics can be turned into educational needs for gifted students. Therefore, effective and successful teachers should know the characteristics of gifted students and they should meet the special educational needs of gifted learners (Heath, 1997;

Pfeiffer & Shaughnessy, 2015) because they are more affected by teachers' attitude and behaviors than non-gifted students (Croft, 2003). Although experienced teachers have necessary knowledge and abilities, these characteristics unfortunately are not enough to meet the needs of gifted students (Bangel, Moon, & Capobianco, 2010; Croft, 2003; Manning, 2006; Miller, 2009; Taber, 2007).

Effective teachers should identify and understand their students, and have a repertory including varied instructional and differentiation techniques such as acceleration, grouping, or highly enriched curriculum. The designing of differentiation activities is very difficult for classroom teachers because these activities require meeting the students' needs, attracting their attentions, addressing individual learning. In order to design a differentiation classroom environment, it requires using deep and extra information, high thinking skills, uncommon subjects, experience, more speed, self-directed learning, which are competencies for effective teachers. In this respect, teachers first identify their students' populations, determine their needs, and find out the ways that handle the needs of gifted students (Croft, 2003).

After determining students' needs, teachers should design specific educational supports including differentiated provisions, and more advanced and varied activities (Sękowski & Łubianka, 2015) because traditional strategies do not support to gifted students (Winstanley, 2007). Therefore, the student-centered instructions are a must, and whoever is gifted in science has to know the nature of science (Gilbert, & Newberry, 2007). In this regard, in order to design effective instructional materials, or enrichment activities, teachers should participate in specific training programs developed to overcome the special needs of gifted students (Kaplan, 2012; Miller, 2009). Moreover, regular educational supports such as formal training or certification programs might not be enough to develop teachers' professional competencies for gifted students due to the fact that those educational attempts generally include SMK on a specific domain (Miller, 2009; Mills, 2003). Teachers need to engage in training programs in which they should gain some special knowledge and abilities so as to enhance creative and productive abilities of gifted students in addition to improve individuals' self-fulfillment and to provide society with gifted students' future attribution (Renzulli, 2012).

In conclusion, the projects, training programs, or educational supports to enhance teachers' knowledge and abilities are very beneficial with regard both students and teachers (Heath, 1997; Johnsen, Haensly, Ryser, & Ford, 2002). Moreover, effective and skillfully teachers have ability to determine students' needs, and handle those by using particular strategies or precautions. The teachers are able to answer how much their students need to take enrichment activities, what degree of speed is more appropriate for the students, and how much challenge and frustration can be tolerated by the students in enrichment activities? (Pfeiffer & Shaughnessy, 2015). In this respect, to find out the answer to above questions, it is necessary to have teachers with strong knowledge bases especially PCK.

1.1 Purposes of the Study

In light of the rational of the study, the study had two main purposes (1) to investigate the nature of topic-specific PCK while the teacher of gifted students was teaching work and energy, simple machines, and friction force topics, and (2) to investigate the interaction among all PCK components both planning and practicing process while teaching of related physics topics.

1.2 Research Questions

1. What is the nature of PCK of gifted students' science teacher in teaching the topics of work/energy, simple machines and friction force?

a. What is the nature of gifted students' science teacher's knowledge of orientation to science teaching in teaching the topics of work/energy, simple machines and friction force?

b. What is the nature of gifted students' science teacher's knowledge of curriculum in teaching the topics of work/energy, simple machines and friction force?

c. What is the nature of gifted students' science teacher's knowledge of learner in teaching the topics of work/energy, simple machines and friction force?

d. What is the nature of gifted students' science teacher's knowledge of instructional strategy in teaching the topics of work/energy, simple machines and friction force?

e. What is the nature of gifted students' science teacher's knowledge of assessment in teaching the topics of work/energy, simple machines and friction force?

2. How do PCK components interplay in teaching the topics of work/energy, simple machines and friction force?

a. How do PCK components interplay in the lesson planning while teaching the topics of work/energy, simple machines and friction force?

b. How do PCK components interplay in the classroom practices while teaching the topics of work/energy, simple machines and friction force?

1.3 Definition of Important Terms

This part of the study explained the important concepts mentioned in many part of the study, and they need to be identified.

Pedagogical Content Knowledge is a;

> "teacher's understanding of how to help students understand specific subject matter. It includes knowledge of how particular subject matter topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction." (Magnusson, et al., 1999, p. 96).

Subject Matter Knowledge means the knowledge including the amount and organization of content in a particular domain. Knowledge of the content involves theories, principles, models, organizations of concepts, and facts (substantive structure), and the way and process of obtaining knowledge with using the rule of evidence and proof to support scientific claims in a specific field (syntactic structure) (Schwab, 1964, as cited in Tamir, 1988).

Pedagogical Knowledge refers to general teaching knowledge and behaviors such as general instructional strategies, learning theories, communication skills, and behavior and classroom management (Abell, 2007). It is also not a subject specific knowledge for specific teachers such as science teaching or mathematics.

Science Teaching Orientation (STO) refers that teachers have knowledge and beliefs about goals and purposes at a particular grade level. Moreover, orientation is conceptualized a general view of teaching science. In other words, this component is defined general teacher's view of teaching and knowledge of teacher's purposes and goals toward in planning, teaching, and evaluating of a specific science topic (Magnusson et al., 1999).

Knowledge of Curriculum (KoC) contains two knowledge bases; mandated goals and objectives for learners in a subject (physics, chemistry, or biology), and specific curricular programs and materials (Magnusson et al., 1999).

Knowledge of Learner (KoL) is about learns to help students develop scientific knowledge and includes two sections such as knowledge of requirements for learning and knowledge of areas of student difficulty (Magnusson et al., 1999).

Knowledge of Instructional Strategies (KoIS) consists of two parts. (1) Subject-specific strategies are related to general approaches for science teaching. Teachers' general teaching views mentioned in STO component include learning cycles, discovery, conceptual change, or inquiry strategies which are used to reach specific goals and purposes. (2) Knowledge of topic-specific strategies is teacher knowledge to provide students' understanding about specific topics. Teachers can use representations such as "illustrations, examples, models, or analogies" and activities such as "example, problems, demonstrations, simulations, investigations, or experiments" (Magnusson et al., 1999, p.111).

Knowledge of Assessment (KoA) includes the knowledge of dimensions of science learning to assess (assessment process for a science topic such as scientific literacy including conceptual understanding, nature of science, scientific investigation and assessing) and knowledge of methods of assessment (teacher knowledge about assessment ways to evaluate learning that occur in students while teaching a specific topic such as written test, journal entries, laboratory reports multiple choice tests) (Magnusson et al., 1999).

Interaction of PCK component refers that teachers use two or more components together in order to provide a presentation, to handle a misconception, or to detect and handle a learning difficulties while teaching a specific content (Park & Oliver, 2012) because the teachers PCK components act coherently as a whole (Magnusson et al., 1999).

Gifted students have some special abilities in academic domain and present a special performance especially intellectual functioning different from their peers (Gagne, 2004; Gilman, 2008; Taber, 2007). Moreover, gifted student means that a child is identified by experts on intelligence, creativity, artistic, leadership capacity, or specific academic areas in which he or she exhibits high levels of performance than their peers of children (Ministry of National Education (MNE), 2007).

Characteristics of gifted students mean that gifted students, in general meaning, demonstrate cognitive ability such as rapid learner, thinking complex and quickly, advanced comprehension for abstract ideas (Joffe, 2001; Manning, 2006; Miller, 2009; Park & Oliver, 2009; Taber, 2007), and transferring effectively obtained knowledge and implement it to new conditions (Manning, 2006; Miller, 2009; Stott & Hobden, 2016), for emotional ability such as having perfectionist traits to complete any works (Joffe, 2001; Park & Oliver, 2009), dislike routine, notetaking, and homework (Joffe, 2001; Park & Oliver, 2009; Samardzija & Peterson, 2015), enjoy participating complex, discovery, students-centered, self-discovery learning environment (Friddyment, 2014; Joffe, 2001; Miller, 2009; Samardzija & Peterson, 2015; Taber, 2007).

Enrichment curriculum or activities is defined that regular curriculum subjects including ideas and knowledge are extended, supported, or differentiated to greater extent with high level of context, knowledge or ideas in order to meet the gifted students' needs (Freeman, 1998; Thomson, 2006).

1.4 Significance of the Study

This study included two powerful aspects; analyzing the nature of topic-specific science teacher of gifted students' PCK, and investigating the interactions among the science teacher's PCK component while both planning and teaching practicing of the topics "work and energy, simple machines, and friction force". In doing so, it is hope that each of them provides in the field of science and gifted teacher education with valuable evidence.

This study was a part of science teacher education through investigating topic-specific in nature. After Shulman's (1986) definition of PCK, a large number of scholars have conducted PCK studies in order to provide in the field of teacher education with valuable information about teachers knowledge and abilities, and each of them supported to teacher education fields by adding new components (Grosman, 1990; Magnusson et al., 1999; Marks, 1990; Tamir, 1988), new methodologies (Gess-Newsome, Taylor, Carlson, Gardner, Wilson, & Stuhlsatz, 2017; Kaya, 2009; Padilla & van Driel, 2011; Park & Chen, 2012), new definition and models (Gess-Newsome, 1999; 2015; Park & Oliver, 2008) of PCK. However, it is not clear yet the science teacher education in terms of how teachers use their PCK or how their students affect teachers' PCK while teaching particular topics. In addition, science teacher education needs to be conducted more topic-specific PCK studies (Abell, 2008; Loughran et al., 2004; van Driel et al., 1998). Moreover, there are still unclear points in PCK, which requires to be reached consensus (Bertram & Loughran, 2012; Gess-Newsome, 2015; Schneider & Plasman, 2011) such as the relationships between teachers' STO and other components (Friedrichsen, van Driel, & Abell, 2011), effectiveness of teachers' KoIS including inquiry skills and models; how they translate into classroom practice; and teachers' KoA (Abell, 2007), and teachers' KoC (Park & Chen, 2012). If PCK is considered a paradigm for science teacher education and researchers, each piece of the puzzle should be completed by further research that compares and contrasts teachers' knowledge in different topics in the same branch (Abell, 2008). In this respect, the current study including the nature of topic-specific PCK with physics topics was supposed to find out a piece of the puzzle in the field of science teacher education.

In addition, so as to complete the piece of puzzle of PCK, topic selection needs consideration because large number of scholars have studied topic-specific PCK such as biology topics (Cohen & Yarden, 2009; Friedrichsen & Dana, 2005; Käpylä, Heikkinen, & Asunta, 2009; Tekkaya & Kılıç, 2012), chemistry topics (Aydın, 2012; de Jong, van Driel, & Verloop, 2005; Demirdöğen, Hanuscin, Uzuntiryaki-Kondakci, & Köseoğlu, 2016; Park & Oliver, 2008; van Driel, de Jong & Verloop, 2002; van Driel, et al., 1998), and physics topics (Etkina, 2010; Findlay & Bryce, 2012; Halim & Meerah, 2002; Nilsson, 2008; Seung, 2013). When comparing the topics to be subjected in PCK studies, physics topics have taken less attention specifically in Turkish context (Aydın & Boz, 2012), and when comparing physics topics in the same discipline, researchers especially focused on mechanical issues (Eyyüpoğlu, 2011). Following PCK studies focusing on physics topics which were used to analyze in a variety from pre-service teachers to in-service teachers, from elementary level to secondary level, or undergraduate course topics such as linear motion (speed, velocity, and acceleration) and thermodynamics (heat energy and temperature) (Veal, Tippins & Bell, 1999), force and electric circuits (Loughran et al., 2004), light, speed, force, heat (Halim & Meerah, 2002), heat energy and temperature (Magnusson & Krajcik, 1993), force in floating and sinking (Parker & Heywood, 2000), thermal physical phenomena (Sperandeo-Mineo, Fazio, & Tarantino, 2006), electricity and magnetism (Eyüpoğlu, 2011), matter and interactions (Seung, 2012), and electricity, mechanics, temperature, light, and sound (Nilsson, 2008). This present study had originality in terms of physics topics comparing with above studies including generally high school physics topics. The previous studies also did not have topic-specific in nature (Loughran et al., 2004). They generally examined the relationships between SMK and teachers' teaching (Parker & Heywood, 2000; Sperandeo-Mineo et al., 2006), PCK development process and the effect of content knowledge on teachers' PCK (Veal et al., 1999), or few specific components such as KoL or KoIS (Halim & Meerah, 2002; Magnusson & Krajcik, 1993). Stated differently, they have different characteristics from topic-specific PCK studies. However, the study investigated physics topics work and energy, simple machines, and friction force in the middle school level, and topic-specific in nature with five PCK components.

As the selection of the topics; work and energy, simple machines, and friction force were investigated because each topic has different features such as curriculum objectives, materials, difficulties and abstract levels, and they were not studied based on topic-specific PCK in middle school levels, and gifted students' context yet. In this respect, after analyzing and drawing a conclusion about the participant science teacher's PCK, behaviors or valuable teaching practices will fulfill several gaps about issues mentioned science teacher and gifted students' education literature. The valuable and significant knowledge and abilities provide (1) in-service teachers working with gifted and non-gifted students with an alternative example of how teaching and learning appear in the classroom context while teaching of three physics topics, (2) pre-service teachers preparing programs with modification or redesigning programs through getting specific application or activities and concrete example of PCK arising from the study topics.

To sum up, the study results were hoped to be a significant resource both in-service teachers and pre-service teachers in terms of professional development of teachers because the study topics have an abstract, difficult, and complex nature for learning and teaching (Hammer, 1996). Moreover, both teachers and students believe that understanding of physics topics requires engaging in difficult process (Ahtee & Johnston, 2006). In addition to their abstract and complex nature, both pre-service and in-service teachers have many alternative conceptions about work and energy (Avcı, Kara, & Karaca, 2012; Çoban, Aktamış, & Ergin, 2007; Kruger, 1990; Trumper, 1998; Yürümezoğlu, Ayaz, & Çökelez, 2009), simple machines (Marulcu & Barnett, 2013), and friction force and energy (Atasoy & Akdeniz, 2007; Hançer, 2007; Hope & Townsend, 1983; Kaplan, Yılmazlar, & Çorapçıgil, 2014). Therefore, it was expected that the participant teacher would present valuable pedagogical decision making process and teaching behaviors which are important sources and examples of teaching and learning of three physics topics in terms of in-service teacher and pre-service teacher professional developments.

The significance of the study also arose from the study context including real teaching environment. A middle school science teacher was analyzed in the study in terms of Magnusson et al.'s (1999) PCK model and five components. As we know that teachers use their PCK, and all components act coherently as a whole while teaching specific topics. The absence of one or more components in a study context might inhibit to obtain better understanding of teachers' knowledge and behaviors (Magnusson et al., 1999). Some studies aimed to investigate the teachers PCK with only two or three components; namely, they did not utilize all components in a study. Besides, in the light of the literature, some studies mentioned above included study context in which pre-service teachers were engaged. As we know that pre-service teachers do not present a strong knowledge and behaviors as well as experienced teachers (Magnusson et al., 1999; Shulman, 1987). In this study, participant teacher had three years teaching experience, namely, the teacher was neither a pre-service teacher nor an expert teacher. She was only in her induction period of professional development. Induction period is that transition process from student to expert teacher. Stated differently, Induction period is defined as "the first three years of teaching" (Paese, 1990, p.159) and it is the first professional development of teachers (Urzua, 1999). In this respect, the participant teacher has gradually given up her beliefs arising from pre-service teaching experiences, and she has faced real teaching context. She has also experienced the large number pedagogical difficulties while teaching particular science topics, and each of pedagogical difficulties provided with valuable knowledge and behaviors. Moreover, the more pedagogical difficulties a begging teacher faced in teaching practices, the more likely strong PCK appeared. As a conclusion, engaging in-service teacher who was in induction experiences and analyzing all PCK components in the current study increased the significance of the study, and it was hoped that the study context provided valuable information about the teacher knowledge and practices.

The investigating interaction PCK components increased the contribution of the study to science teacher education because science teacher scholars agree that PCK studies need to consider the relationships among PCK components (Abell, 2008; Magnusson et al., 1999). Moreover, there are few studies investigating the interactions in order to better understanding the teachers' practical knowledge (Friedrichsen et al., 2011). However, some of the studies have emphasized the need for more interaction studies (e.g., Abel, 2007; Cochran, King, & DeRuiter, 1991; Fernandez-Balboa & Stiehl, 1995; Magnusson et al., 1999) as well as conducting evidence based research (Park & Chen, 2012) to obtain better understanding of teachers PCK. To date, some studies have investigated the relationships among knowledge bases such as SMK, PK, and PCK (e.g., Fernandez-Balboa & Stiehl, 1995; Friedrichesen, Abell, Pareja, Brown, Lankford, & Volkmann, 2009; Henze, van Driel, & Verloop, 2008). Some other studies have provided with evidence based results to portray the interactions among teachers' PCK components (Akın, 2017; Aydın & Boz, 2013; Aydın et al., 2015; Demirdöğen, 2016; Ekiz Kıran, 2016; Pandilla & van Driel, 2011; Park & Chen, 2012). On the other hand, in this respect, chemistry teachers (pre-service or in-service) and chemistry topics were generally utilized in above studies including the interactions of PCK components. However, to the best of my knowledge, there is no study investigating the interactions of PCK components in physics topics. As a conclusion, the second aim of the study was to investigate the interaction of teacher' PCK components both planning and practicing process of the topics of work and energy, simple machines and friction force. Therefore, if we considered missing paradigm as interaction of PCK component field, the current study could be a piece of the puzzle to be needed completed.

The last significance of the study, but not the least, was to have gifted students in classroom context. Given the importance of science teacher PCK, gifted students' teachers also need to be engaged in a professional development process so as to handle the special needs of the gifted students arising from their characteristics in classroom context. In the field of gifted students' education, the large number of scholars agree that gifted students' education requires to be conducted much more evidence based researches (Coleman, 2014; Gilbert & Newberry, 2007) especially teacher education (Joffe, 2001; Park & Oliver, 2009).

In the gifted education, there are some studies about gifted students educations, for example, enrichment curriculum or activities (Heath, 1997; Johnsen, et al., 2002), achievement and socioemotional outcomes (Kim, 2016), teachers and students motivation toward science, teachers' confidence to design and implement for enrichment activities (Newman & Hubner, 2012), students' achievement, science process skills, and attitude toward science (Çalıkoğlu & Kahveci, 2015), students' analytical and critical abilities (Aljughaiman & Ayoub, 2012), and teachers' knowledge and perceptions about gifted students (Bangel et al., 2010; Chan, 2001; 2011). In this respect, these studies are generally related to gifted students' achievement, identification of gifted students, or teachers' perceptions, however, the empirical studies focusing on science education is not easy to find out (Gilbert & Newberry, 2007; Winstanley, 2007). Traditional strategies do not support to gifted students' education so different type pedagogical studies are required for obtaining empirical evidence. Furthermore, topic-specific studies provide more valuable information about development of both teachers and students' skills (Winstanley, 2007).

To sum up, weak and inadequate opportunities fail to notice gifted students, and hinder to enhance their special abilities. Although some efforts or attempts are offered for teachers to enhance knowledge of characteristics of gifted students, these supports are not enough for science teacher applications. Therefore, teachers need to increase pedagogical repertories to design and to apply related instructions (Gilbert & Newberry, 2007). This present study might help to development of teachers' pedagogical repertories by clarifying how a specific science topic is designed for learning of gifted students, and what the reactions of gifted students are to instructional strategies, and the teacher's valuable pedagogical strategies to overcome particular learning difficulties derived mainly from the complex and abstract nature of physics concepts. In doing so, the best effective and successful learning environment is tried to create for gifted students' education. As a conclusion, it is essential to recognize the gifted students' needs and to deal with them by using appropriate ways and different views (Croft, 2003).

Along this line, the present study provided in field of science teacher education with understanding of the relationships among gifted students' characteristics, and the teachers' pedagogical decisions and practices. Moreover, this study helped to understand more sophisticated comprehension of how the gifted students effect on the teacher' PCK.

CHAPTER 2

LITERATURE REVIEW

In this part of the study, literature review about PCK models, studies, theoretical background of PCK, gifted education were presented in the five sub-titles; (1) definition PCK and historical development of PCK models, (2) research on science teachers' topic specific PCK, (3) research on interaction of PCK components, (4) gifted students' education and their teachers, and (5) conceptualization of PCK for this study.

2.1 Definition of PCK and Historical Development of PCK Models.

The investigations focusing on competencies of teacher had been changed from content knowledge to general pedagogy. However, these two knowledge types were not considered together in teacher education research, which was called missing paradigm by Shulman (1986). Shulman and his colleagues in their study of "knowledge growth in teaching" emphasized that content and general pedagogy would not be investigated separately. Therefore, they suggested that content knowledge was considered in three categories; subject matter content knowledge, pedagogical content knowledge, and curricular knowledge. They also identified that PCK is "the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations-in a word, the ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, p. 9). Another Shulman's (1987) study investigated the development teachers' content knowledge and pedagogy. They determined knowledge bases to create a framework in order to achieve meaningful learning. In addition to Shulman's (1986) study, according to Shulman (1987) there should be at least knowledge bases as follows; “general pedagogical knowledge, knowledge of learners and their characteristics, knowledge of educational contexts, knowledge of educational ends, purposes, and values, and their philosophical and historical grounds” (p.8). In this regard, Shulman (1987) identified PCK as “special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional” (p.8).

After Shulman’s works related to knowledge bases, PCK has been utilized many scholars in their research and they have extended PCK. For example, Tamir (1988) organized the knowledge bases of Shulman’s works in order to offer a more useful and comprehensible framework for teacher education. Tamir payed attention to SMK, general PK, and subject matter specific pedagogical knowledge which were similar with Shulman’s ideas but each knowledge type divided into two sub-categories as knowledge such as “specific common conceptions and misconceptions in a given topic” and skills such as “how to diagnose a student conceptual difficulty in a given topic” (Tamir, 1988, p.100). Moreover, general pedagogical knowledge and subject matter specific pedagogical knowledge include four components such as student, curriculum, instruction, and evaluation in the Tamir’s framework and assessment part for each knowledge were underlined a necessary knowledge base for teacher education.

Grossman (1990) is another scholar to enhance Shulman’s works. She designated teachers’ competencies as SMK, general pedagogical knowledge, PCK, and knowledge of context. She also emphasized the importance of contextual knowledge arising from teachers’ background. In order to show the effect of teachers’ background, she investigated six teachers (three of them had pedagogical preparation and others did not have) and their teaching. She used a framework including PCK and its four components such as knowledge of purposes for teaching subject matter, knowledge of students’ understanding, KoC, and KoIS. In other words, Grossman observed the six teachers’ teaching in terms of the framework in order to investigate the effect of subject specific methods courses on the teachers’ professional developments. According to the results, the teachers in the context including subject specific methods courses background demonstrated more active teaching skills than others. Grossman argued the differences of professional development and teachers' goals and purposes based on the teachers' preparation of educational context. Moreover, Grossman (1990) attributed the component of orientation as separated knowledge teachers need to know and she defined teaching orientation as "conceptions of purposes for teaching subject matter" (p. 5). However, her framework did not contain knowledge of assessment.

Marks (1990) remodified and revised the model of PCK based on the mathematics knowledge constructions by investigating PCK of fifth grade mathematic teachers. In this study, eight mathematics teachers were interviewed in terms of PCK as a central idea while they were teaching, determining, and handling students' difficulties. Marks portrayed PCK in four major areas: "subject matter for instructional purposes, students' understanding of the subject matter, and media for instruction in the subject matter (i.e., texts and materials), and instructional processes for the subject matter" (p.3). Figure 2.1 shows the detail information about description of PCK in mathematics. In this model, media is a knowledge used in instructional processes and being required for instruction. In other words, unlike other PCK models (Grossman, 1990; Shulman, 1987), new knowledge type "media" was integrated into a PCK model. Moreover, Marks mentioned knowledge of curriculum and assessment and placed them under the component of instructional process. In this respect, PCK sources were identified and three possible sources formed the PCK. The first PCK source was SMK, and its general definition was explained in that source as transforming content knowledge through useful representations. The second PCK source was related to general pedagogical knowledge. A teacher should adjust general pedagogical knowledge to specific context where teaching occurs. The last source was transformation and representation abilities arising from SMK or general pedagogical knowledge. It also refers to formulation of teaching activities, selection of instructional strategies, consideration students' learning difficulties. Author briefly stated that PCK was arisen from a synthesizing of the three knowledge sources rather than transforming only SMK and general pedagogical knowledge.

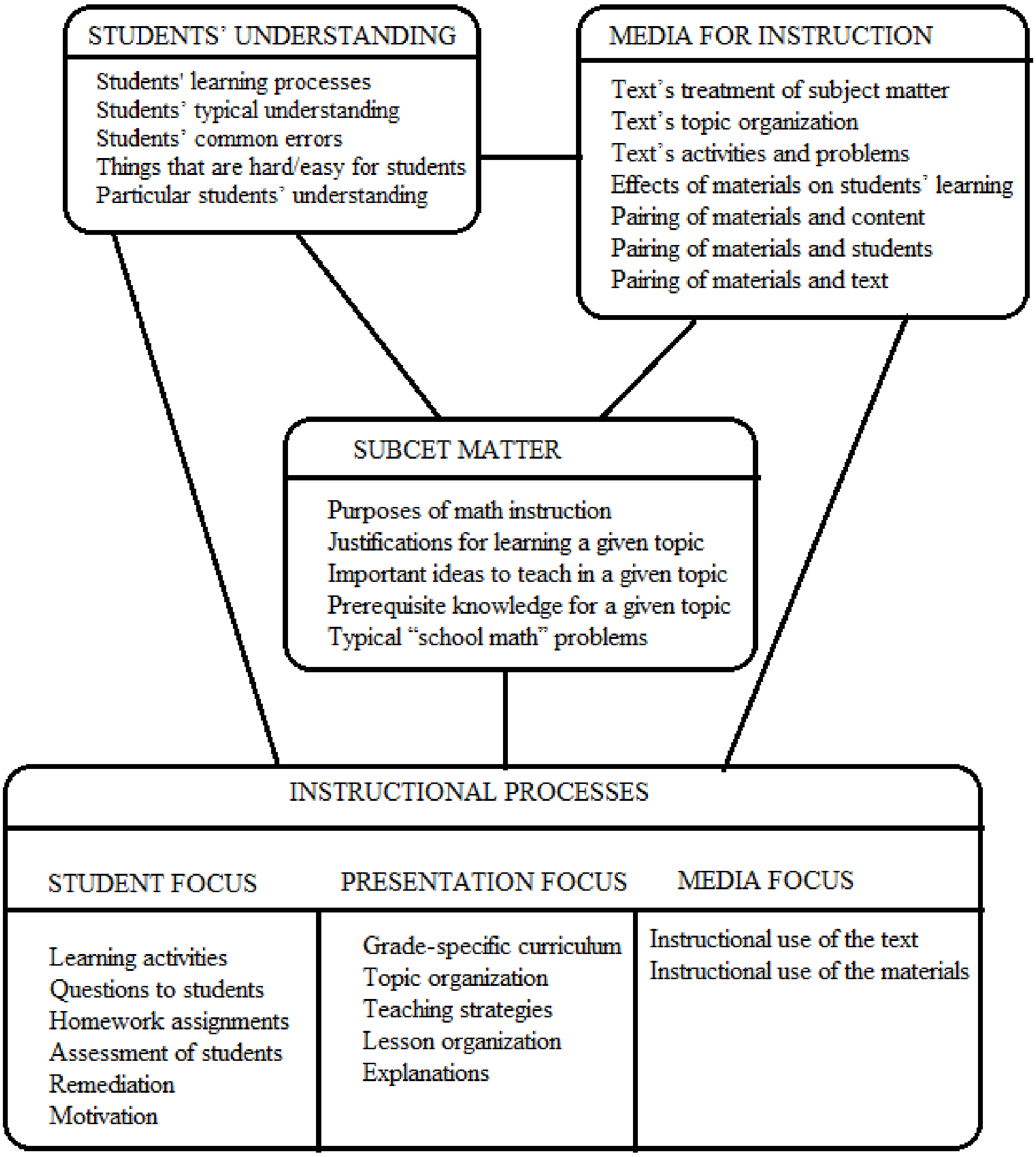


Figure 2.1. Marks' PCK models

Other researchers who worked with Shulman' PCK framework were Veal and MaKinster (1999). They critiqued that previous researchers used PCK as an analytic framework but they did not classify knowledge based as taxonomies. Therefore, they aimed to illustrate PCK components or attributes' hierarchical relationships in the sample of secondary science teachers. They categorized pedagogy into three major groups such as general PCK, domain-specific PCK, and topic specific PCK. General PCK refers to having knowledge about pedagogical concepts, strategies, and applications which are used by all teachers related to particular disciplines such as science, mathematics, or history. For examples, general PCK strategies might include "planning, teaching methods, evaluation, group work, questioning, wait time, feedback, individual instruction, lecture, demonstration, and reinforcement" (Veal & MaKinster, 1999, p.7). The second level PCK in the taxonomy is domain-specific PCK. It implies one specific domain among different disciplines or subject matters. For example, science discipline includes particular specific domains; physics, chemistry, or biology. Each domain has specific pedagogical applications or skills that require being performed by effective teachers. For examples, pedagogical applications in the chemistry laboratory differ from other domain laboratories and need to have different PCK competencies. The third level in the taxonomy is topic specific PCK. It is the most distinct PCK than other levels. Specific topics in a particular domain or subject require having special abilities or applications (e.g., force and motion, work and energy in the physics subject, and cell, photosynthesis, human anatomy in the biology subjects). In order to obtain effective learning in related topics, instructional strategies, methods, assessments, and students' knowledge have different nature. Thus, topic-specific PCK researches have been as a missing paradigm (Abell, 2008), and broadly used in the science teacher education.

Development of PCK model was continued with the definition of Magnusson et al. (1999). Similar to Grossman's (1990) definition, they considered PCK as a transferring of knowledge (SMK, PK, contextual) to new type of knowledge and they integrated beliefs in knowledge bases. By adding beliefs into model, they argued that teachers' pre-knowledge and beliefs serve as filters while planning and teaching any specific topics. PCK was defined as follows (Magnusson et al., 1999);

> Pedagogical content knowledge is a teacher understanding of how to help students understand specific subject matter. It includes knowledge of how particular subject matter topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction (p. 96).

Their understanding of science teacher's knowledge model includes four main knowledge bases such as SMK and beliefs, PK and beliefs, PCK and beliefs, and knowledge and beliefs about context that are shown in Figure 2.2. PCK affects and is affected by the other knowledge domains because it is composed of transformation of other knowledge. In this respect, SMK provides teachers with a strong resource to teaching a particular topic but SMK is not solely adequate to develop PCK. Other knowledge domains are also enhanced as much as SMK. For example, school context including disabilities students or gifted students requires knowledge of specific educational aims, instructional principles, or classroom management differing from regular school context. It is expected that effective teachers reflect the knowledge bases effectively on their teaching.

Magnusson and her colleagues also explained the PCK with five components as shown in Figure 2.3. *Orientations toward teaching science* component (STO was used as an abbreviation of science teaching orientation for this component in the current study) refers that teachers have knowledge and beliefs about goals and purposes at a particular grade level. Moreover, orientation is conceptualized as a general view of teaching science. In other words, this component is defined as a general teacher's view of teaching and knowledge of teacher's purposes and goals toward in planning, teaching, and evaluating of a specific science topic (Magnusson et al., 1999). This component was emerged from Grossman's (1990) definition of knowledge of purposes for teaching subject matter. Magnusson and her colleagues refined Grossman's conception to orientations toward teaching science. In this respect, STO includes objectives, decision-making process, instructional strategies, and assessment materials or curriculum materials while teaching and planning a particular science topic. Furthermore, Magnusson and her colleagues organized STO by taking the teaching process into consideration as shown in Table 2.1. Each teaching process or scenario such as academic rigor, didactic, or inquiry reflects STO's main role during planning and teaching process of a specific science topic.

Knowledge of science curriculum (KoC) component separates the pedagogue from the content specialist so this knowledge is utilized as a component of PCK. This component also contains two knowledge bases; mandated goals and objectives, and specific curricular programs and materials. First knowledge base is comprised of teacher knowledge of goals and objectives for learners in a subject (physics, chemistry, or biology) which needs to be learned by students during one school year period. This component also includes vertical curriculum knowledge meaning which concepts were learned by students in previous years and will be learned in the next years.

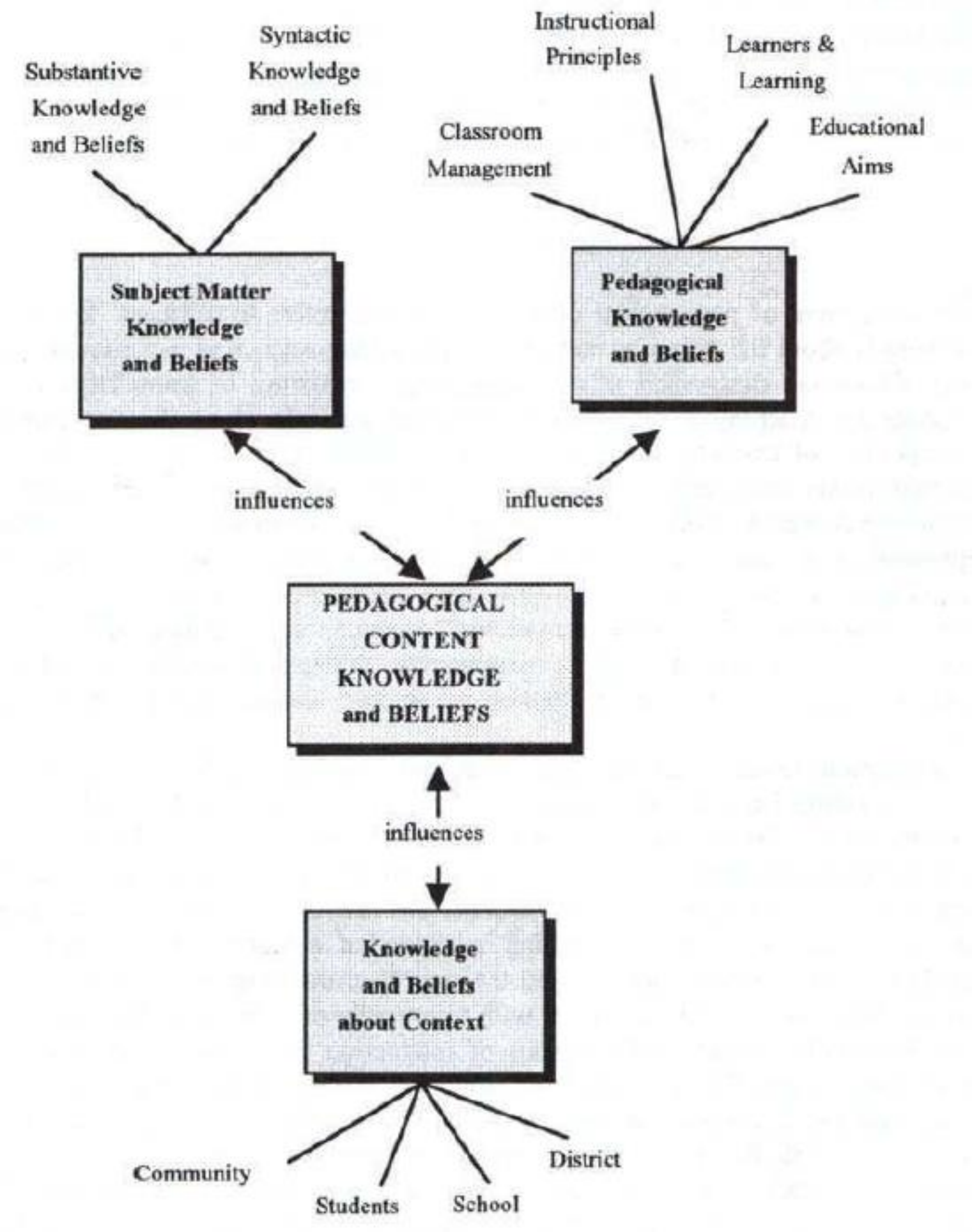


Figure 2.2. The Relationships among Knowledge Domains of Magnusson et al. (1999, p.98).

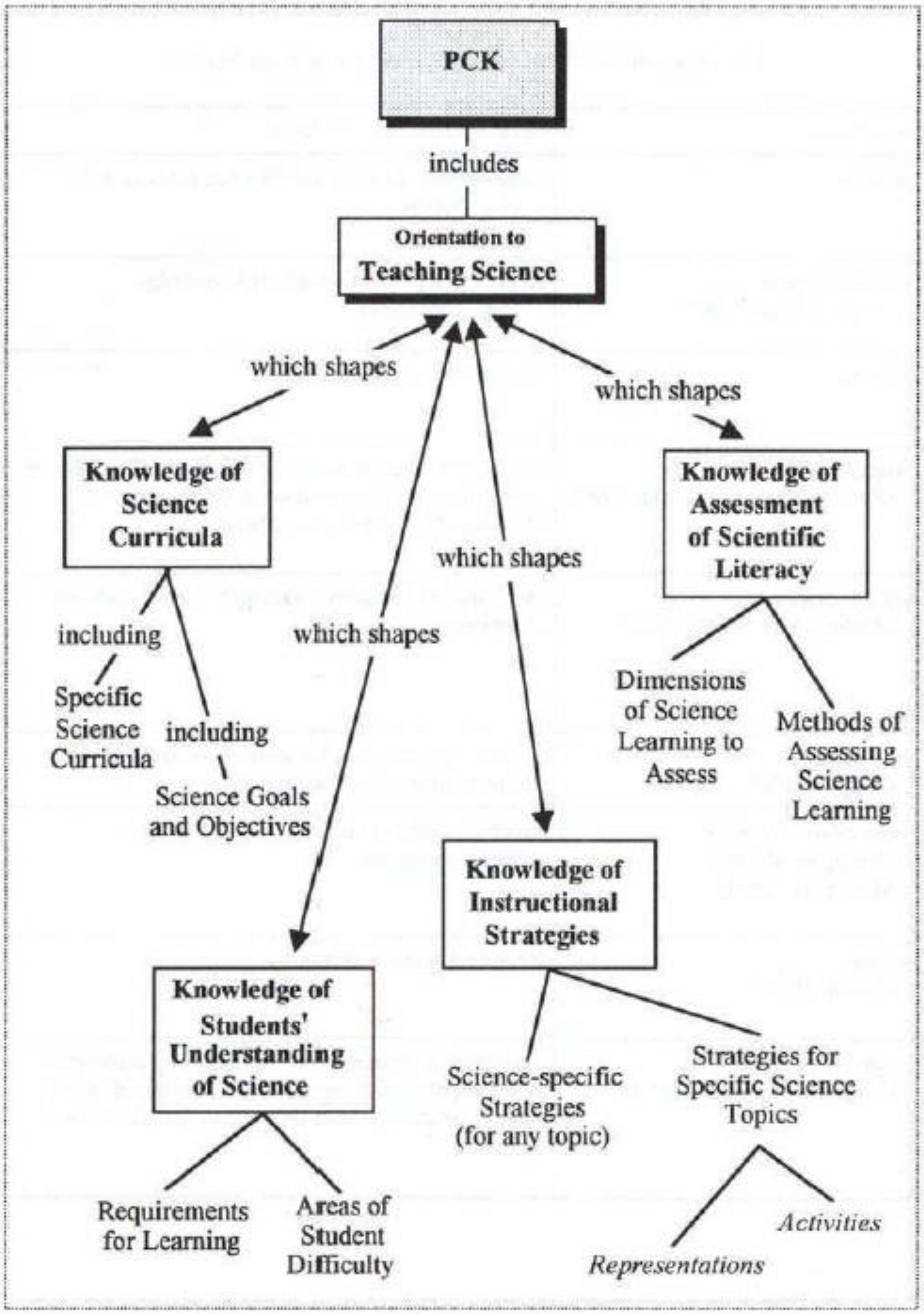


Figure 2.3. PCK and Its Components for Science Teaching (Magnusson et al., 1999, p.99)

Table 2.1. The Goals of Different Orientations to Teaching Science

Orientations	Goal of teaching science
Process	Provide students to enhance their science process skill abilities
Academic rigor	Introduction of a particular body of knowledge Students are engaged in difficult problems and activities.
Didactic	Transfer the facts of science Information is introduced by utilizing lecture or discussion.
Conceptual change	Simplify the construction of scientific knowledge through contradicting students with cases to clarify that challenge their alternative conceptions.
Activity-driven	Engage students in hands-on activities in order to verify or discover scientific knowledge
Discovery	Create an environment for learners to explore science concepts on their own interests
Project-based science	Engage students in investigation process to solve authentic problems
Inquiry	Engage students in inquiry process to define problems, to investigate them, to reach conclusions, and assess the validity of knowledge
Guided inquiry	Organize a group of students whose participants share responsibility to understand the nature of scientific knowledge, specifically using the tools of science.

On the other hand, second knowledge base of specific curriculum program refers knowing materials and programs for teaching a subject. Over half a century, science curricula have been developed or subjected to modifications. Therefore, science teachers are expected to know the development or changes.

Knowledge of students' understanding of science component (KoL was used as an abbreviation of knowledge of learner for this component in the current study) is about learners to help students develop scientific knowledge and includes two sections such as knowledge of requirements for learning and knowledge of areas of student difficulty.

The first knowledge base of requirements for learning refers to teacher knowledge about knowledge and abilities that students would need for learning. Students might have different development level, learning styles, or abilities and teachers should know these requirements in order to teach particular topics in easier and more comprehensible way. In other words, knowledge of requirements for learning means to realize all these differences. Moreover, effective science teachers should know students' learning needs and meet these needs though facilitating appropriate methods.

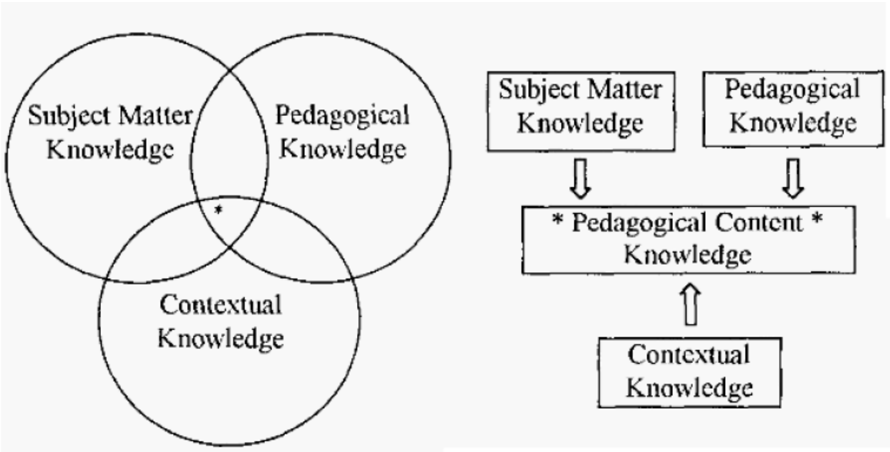
The second knowledge type is the knowledge of areas of student difficulty. This knowledge includes science concepts challenging the students and leading learning difficulties, or alternative conceptions. Abstract concepts, problem solving ability, misconceptions, prior knowledge, and all these factors might affect both teachers' teaching and students' learning. Therefore, teachers should be aware of these learning difficulties and common mistakes about science concepts. Finally, knowledge of areas of students' difficulty helps teachers correctly interpret their students' actions and ideas.

Knowledge of assessment in science component (KoA) was first offered by Tamir (1988) and Magnusson and her colleagues utilized as a PCK component. This component is composed of knowledge of dimensions of science learning to assess and knowledge of methods of assessment. The first one is related to knowledge about assessment process for a science topic. Magnusson et al. (1999) indicated scientific literacy for assessment in their PCK model. Scientific literacy includes some dimensions such as conceptual understanding, nature of science, scientific investigation and assessing and evaluating for each dimension which requires having specific knowledge and abilities. Thus, effective teachers should know which dimension of scientific literacy to assess and which properties of those dimensions to assess on teaching a science topic. On the other hand, second one is the knowledge of assessment methods. This knowledge is related to teacher knowledge about assessment ways to evaluate learning that occurs in students while teaching a specific topic. There are many ways of evaluation and its methods such as written test, journal entries, laboratory reports, multiple choice tests but it is not appropriate to apply the same evaluation method for all cases. Each method is applied to reach a specific goal and it has advantages and disadvantages in terms of science topics and scientific literacy dimensions.

Knowledge of instructional strategies (KoIS) is the last component and consists of two parts. First one is knowledge of subject-specific strategies related to general approaches for science teaching. Teachers' general teaching views mentioned in STO component include learning cycles, discovery, conceptual change, or inquiry strategies which are used to reach specific goals and purposes. Teachers with this knowledge require knowing application skills of subject specific strategies and their steps. The second type of knowledge in this component is knowledge of topic-specific strategies. It is teacher knowledge to provide students' understanding about specific topics. In order to reach goals and purposes, teachers can use representations such as illustrations, examples, or models and activities such as problems, demonstrations, simulations, investigations, or experiments. However, each representation or activity has own teaching nature. For this reason, any activity or representation cannot be applied to teaching of all science concepts. Effective teachers are knowledgeable about selection and representation of the activity when they design and implement science teaching.

As a summary, while science teaching, each PCK component appears to be a different type of subject specific pedagogical knowledge. In other words, knowledge of components varies from subject to subject. Effective teacher should know all features of PCK and its components in terms of all topics. Moreover, all components act as a whole. Inconsistences among components lead to specific problems on enactment and development of PCK. On the other hand, development of the one or two components is not enough for the development of teacher PCK as a whole because the interactions of components are complex in nature. Therefore, according to Magnusson et al. (1999) it is necessary to give more attention to investigate how PCK component interplay and how the interactions affect science teaching.

When reviewing the previous studies until Magnusson et al.'s PCK model, Shulman (1987) clarified the knowledge bases and introduced first PCK. Then, following researchers focused on the knowledge bases and developed Shulman's point of view. Grossman (1990) studied with Shulman's model of knowledge bases and she separated pedagogical knowledge from PCK. She also defined PCK components as Magnusson et al. (1999) did but her PCK model focused on general teacher education, namely, it was not subject matter specific. In other words, PCK models (Grossman, 1990; Shulman, 1987) did not include science teacher specific knowledge bases. For that reason, Magnusson et al.'s PCK model and its components provide science teacher education with a comprehensive view of PCK and it is employed as a useful heuristic tool than the previous conceptualizations (Abell, 2007).



* knowledge needed for classroom teaching (Gess-Newsome, 1999, p. 12)

Figure 2.4. Integrative and Transformative Models of PCK

In a different way, Gess-Newsome (1999) defined teachers' knowledge bases and grouped PCK models in two main categories; integrative model and transformative model. Integrative model does not include PCK as knowledge bases as shown on the left side in Figure 2.4 but PCK is generated by combination of SMK, pedagogical knowledge, and contextual knowledge. In other words, teaching appears as the intersection of three knowledge bases like mixture of substances. On the other hand, in the transformative model as seen on the right side in Figure 2.4, PCK is a knowledge bases and it is formed by synthesizing inextricably other three knowledge bases. Teaching any topic is affected by only PCK and other three knowledge bases might be discovered by complex analysis. In other words, when involving teaching practice, teachers process SMK, pedagogy, and contextual knowledge which become in transformation process as latent resources. Therefore, PCK is only utilized by teachers to teach particular concepts in the classroom practices.

Another PCK model was offered by Park and Oliver (2008) in order to conceptualize to PCK using insight of empirical evidence and to follow the development of teachers' PCK. They designed a pentagonal PCK model derived from the definition of components of Magnusson et al.'s (1999) PCK model. This pentagonal model provides a heuristic and organizational tool so as to collect and interpret the data. They used multiple case studies including three chemistry teachers, and they collected the data through interviews, observations, teachers' lesson plans and written reflections, and other works including field notes, and students' performance. Moreover, they focused on three chemistry subject matter units in their study. According to the results of study, there were two factors enhancing the developments of PCK. The first one was the knowledge-in-action; it means that the teachers gain some experiences, knowledge, or pedagogy, which arises from during the teaching practices. In other words, the pedagogy is experienced by the teachers revealed through reflection of the teachers in practices where the teachers generate a solution or handle unexpected situations. The second factor was the knowledge-on-action; on the other hand, it means that the teachers gain some experiences, in which some modifications are carried out by the teachers related to topics such as adding new topics or materials or moving ineffective activities after teaching targeted topics or concepts. As a result, the two knowledge bases enhanced the development of teachers' PCK.

Another point about the result of this study was that the authors discovered the effect of the teachers' self-efficacy on their research. It appeared that teacher efficacy was related to teaching methods. When the teachers believed that they had enough knowledge and experiences, they would apply the knowledge and ability in their actual classroom effectively. Therefore, Park and Oliver added teachers' efficacy with context specific and domain specific sub-components to their PCK model. Moreover, students' influences were recognized on their results in order to organize, develop, and validate the teachers' PCK. The students had an effect on the development of teachers PCK by asking difficult and challenging questions or students' creative ideas, by which the teachers engaged in such experience during reflection-on-action process. Another point is that the sub-component of understanding of students' misconceptions played a critical role to shape the teacher PCK while planning, teaching, and assessing related topics. In other words, the teachers believed that misconceptions act as a barrier in their further applications. Thus, they first focused on determining and handling possible students' misconceptions. Finally, Park and Oliver (2008) stated that the teachers' PCK was idiosyncratic. Although each teacher presented a general knowledge and behaviors, they had different characteristics of PCK. The characteristics have been shaped by factors such as the teacher STO, characteristics of students, teaching experiences, and personal characteristics.

According to the results of the study, Park and Oliver developed hexagonal PCK model illustrated in Figure 2.5 under the light of empirical data mentioned above. PCK was placed at the center of the model, and it was developed by the teachers' experiences arising from reflection-in-action and reflection-on-action. This model has six components (adding teacher self-efficacy as a component in the model which is different from Magnusson et al.'s (1999) PCK model) and sub-components (adding learner motivations and interest, which is different from Magnusson et al.'s (1999) PCK model). Moreover, the six components engage in an interactive relation through the development of PCK. In other words, all components should be integrated in the development PCK but enhancing only one component is not enough for the development of the teachers' PCK.

After Shulman's definition of PCK based on cognitive theory, many researchers used, modified, or regenerated definition, research methods, and model of PCK. Therefore, too many ideas have been yielded and critical differences have occurred on PCK literature. In order to clarify these ambiguities, 22 science educators who are active PCK researchers reexamined the conceptualization of PCK. The researchers investigated the definition of the nature of PCK, models, and its relationships with other knowledge bases. Gess-Newsome (2015) explained this reexamination of the constructing of PCK in detail. The researchers worked in small groups and reconsidered their PCK models in terms of the relationship between PCK and other knowledge bases, and assumptions of their models. After all, research teams focused on the development of a single model, and they agreed on the model of "teacher professional knowledge and skills" (TPK&S) as illustrated in Figure 2.6.

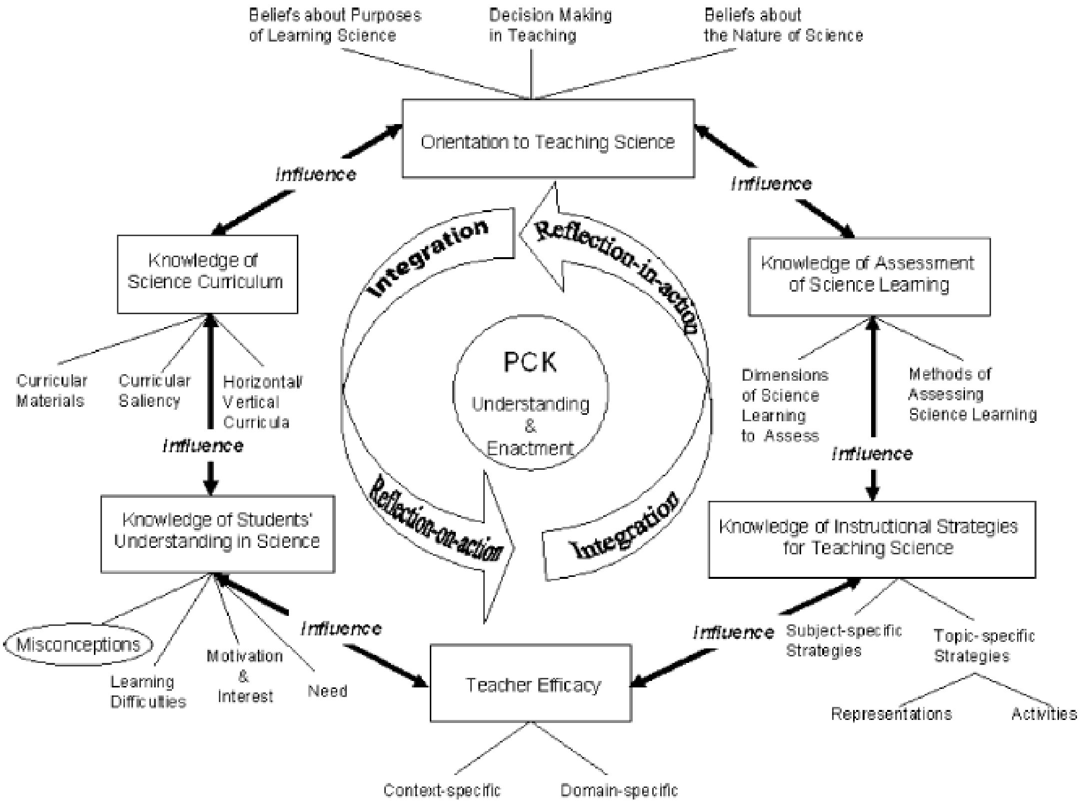


Figure 2.5. Hexagon Model of PCK (Park & Oliver, 2008, p.279)

The research teams particularly struggled to handle the weakness of PCK explained by Shulman (2012); missing parts of PCK (1) emotional and affective aspects of teacher thinking, (2) much more attention on teacher's decision making process than teacher's real classroom teaching, (3) ignoring of context, (4) ignoring a teacher's vision and goals, and (5) students' outcomes. Therefore, as overcoming of the weaknesses, the TPK&S model becomes quite different from Magnusson et al.'s

(1999) PCK model. The researchers agreed that the model of TPK&S has an explanatory feature to guide future researches. It offers a more robust investigation about teacher knowledge and behaviors in a predictive way (Gess-Newsome, 2015).

When looking at the model in Figure 2.6 in detail, teacher professional knowledge bases (TPKB) are seen at the top of the model. Similar to the definition of Shulman, TPKB involves knowledge bases such as assessment knowledge, pedagogical knowledge, content knowledge, students' knowledge, and curricular knowledge. Moreover, TPKB is not content specific, and it provides to measure teacher competencies in terms of knowledge bases. "Teachers are seen as the consumers of this knowledge as translated for use in teacher education programs or professional development" (Gess-Newsome, 2015, p.32). According to Figure 2.6, TPKB involves mutual interaction with topic-specific professional knowledge (TSPK), namely, TPKB affects and is affected by the knowledge.

TSPK is an extension of TPKB and it arises from TPKB in classroom context. It can also be affected by the development of TPKB, in other words, when teacher competencies on any knowledge bases (such as assessment or students) increases, the development of TSPK can be seen. Moreover, TSPK has topic-specific nature and it is affected by the development of characteristics of students' knowledge. It includes "knowledge of instructional strategies, content presentations, students understanding science practices, and habits of mind" (Gess-Newsome, 2015, p.31). In other words, it involves knowledge and skills by which teacher uses during teaching a topic. For example, when considering a particular topic, using questioning technique to determine students' prior knowledge, using simulations to make better understanding, using written format measurement to determine students' misconceptions, etc., regarding above examples, TSPK can be liken to with PCK but an important difference appears. TSPK is static and visible, namely, it is clearly revealed by experts facilitating through coding. "TSPK is canonical, generated by research or best practice, and can have a normative function in terms of what we want teachers to know about topic and context-specific instruction" (Gess-Newsome, 2015, p.33). Moreover, TSPK can be seen to portray through Content Presentation (Loughran et al., 2006) in which there are many questions related to big ideas selected by participant teachers. These standard questions help reveals TSPK and the teachers recognize their TSPK.

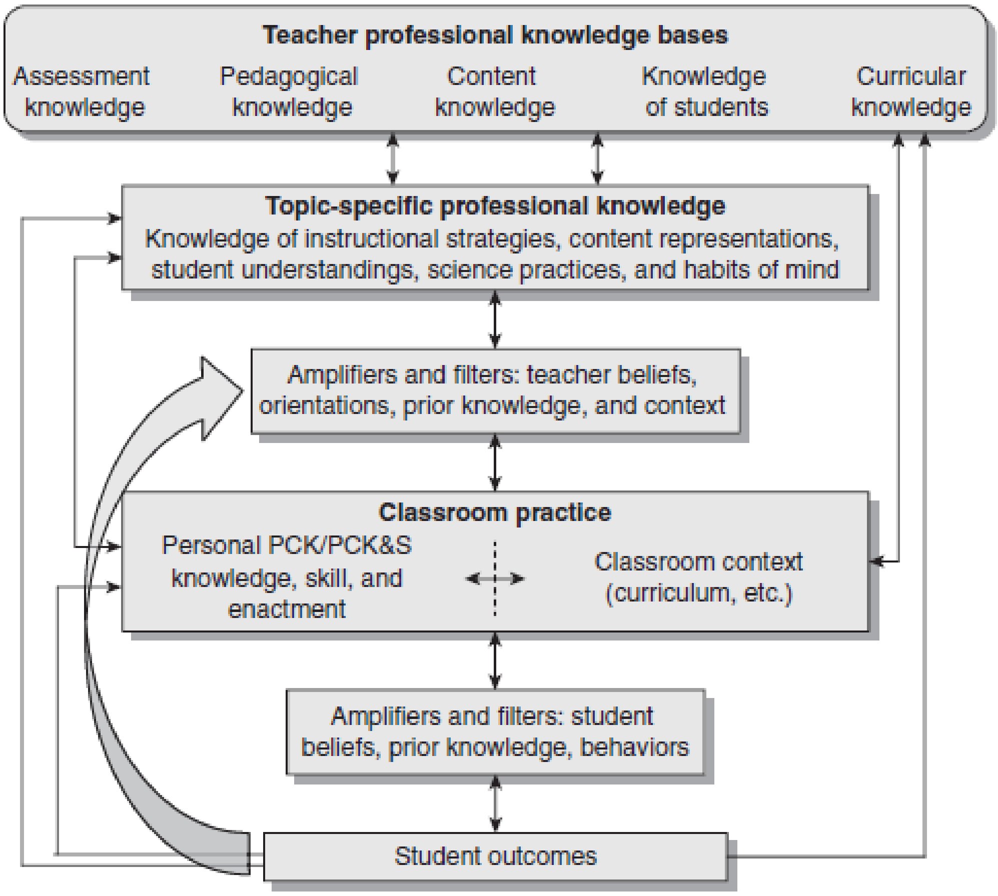


Figure 2.6. Model of Teacher Professional Knowledge and Skill Including PCK and Influences on Classroom Practice and Student Outcomes (Gess-Newsome, 2015, p.31)

Until now, TPKB and TSPK are related to nature of teacher profession and they are gained by educational activities and opportunities. However, teacher amplifiers and filters, which is another knowledge base in the model, are considered as teachers personalize knowledge due to the fact that teachers can design their lessons or applications based on their beliefs, orientation to teaching and learning, or school context. Amplifiers and filters have an effect on teacher teaching, in other words, teachers' beliefs, orientations, prior experiences act as amplifier or filter during teachers' decision making process and teaching practices. Furthermore, amplifiers and filters help to engage the translation of TSPK in teaching process. Contrary to Magnusson et al.'s (1999) PCK model, the component of teacher's orientation and beliefs was removed from PCK, and it was added to amplifiers and filters part of this model. It is believed that the removal of orientation is more accordant with PCK studies, and it allows to better understanding to construct PCK in this model (Gess-Newsome, 2015).

Another part of this model is classroom practices. The researchers focused on this part as a separated title because classroom context has a dynamic structure, in which unexpected situation occurs or the instruction might be completed as planned. Therefore, PCK was located in the classroom practice, and PCK and skill (PCK&S) was defined as follows;

> Personal PCK is the knowledge of, reasoning behind, and planning for teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes (Reflection on Action, Explicit).
> Personal PCK&S is the act of teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes (Reflection in Action, Tacit or Explicit) (Gess-Newsome, 2015, p.36).

Some key points about PCK arise from this definition. First, PCK is a personal knowledge (not public knowledge) and context specific including specific topics, purposes, students, etc. PCK has also a specific experience and it is not generalized. The second point is that PCK and its investigation are separated into two parts; reflection-on-action and reflection-in-action. First one is related to the instructional plans whereas other becomes appear in the act of teaching a specific topic. The third point is that conception of PCK involves skills. Teaching any science concepts requires some skills to present a specific instructional strategies or activities. However, all teachers do not have that skill in a similar level. Thus, integration of skill to PCK model is very important for researchers.

Another knowledge base is student amplifiers and filters in this model. Due to the fact that students shape the teaching and learning in actively, their success or failure influences the teachers' PCK. In this respect, it is focused on external and internal factors to increase or decrease students' achievement during classroom context. External factors are socio-economic status, parental involvement, native language, etc. whereas internal factors are motivation, self-efficacy, self-regulation, intelligence, learning style or approaches, and all the wide range of factors should be investigated as amplifiers and filters.

Students outcomes is another issue discussed in the model because the effects of students' outcomes are felt during all the stages of the model. Students' products and performances are powerful reflection opportunities for the development of teacher knowledge. Teachers can shape their amplifiers and filters by considering feedback according to students' outcomes. Moreover, students' outcomes have the potential for students to modify their amplifiers and filters.

To sum up, Gess-Newsome and her colleagues developed this model "Model of teacher professional knowledge and skills including PCK" as a conceptual tool in order to enlighten future researches. Previous PCK models and definitions have missing parts, many concerns or unclear characteristics. Thus, the research teams focused to handle on those strength and weakness of the previous PCK models and they have agreed on this model.

In conclusion on historical development of PCK models, from introduction of PCK first by Shulman (1986), educational researchers have been interested in how teachers transform their knowledge bases on teaching practices. Early scholars investigated PCK studies about what might construct teachers' knowledge. Therefore, they used different conceptualization, and they offered different PCK models including different components and sub-components. Early models generally involve SMK, PK, knowledge of context, and PCK. One of them is Magnusson et al.'s (1999) PCK model which has been the most cited (Gess-Newsome, 2015). The model considers PCK as transforming other knowledge bases on a new type of knowledge. Although there are many differences on conceptualization of PCK literature, nowadays, educational scholars have agreed on a general model which is called "teacher professional knowledge and skills" (Gess-Newsome, 2015).

2.2 Research on Science Teachers' PCK

In this part, PCK studies were particularly explained in terms of some features; in-service science teachers (as much as possible physics), PCK components, PCK development, and physics topics. This part was restricted above feature because there are abundant PCK studies in science teacher PCK literature, and it is difficult to consider all of them in this part.

The first study in this part is related to STO. Friedrichsen and Dana (2003) focused on eliciting and clarifying both pre-service and in-service science teacher' STO. The participants of the study involved biology teachers and multiple data collection tools were used to investigate teachers' STO such as interviews, observations, and teaching artifacts. The researchers also developed card-sorting task and they applied the card-sorting task with interview. In other words, they enriched their data by using interview in which process the participant teachers reflected their opinion about each scenario because using only card-sorting activities revealed the limited information about STO. After completing the scenarios, the researchers argued that the card-sorting task is a useful tool in order to portray teachers' orientations and beliefs. Moreover, the results of study showed that STO has complex in nature and they were not easily categorized in any scenario. The scenarios were grouped by the teachers in different way. The pre-service teachers were likely to ask extra questions to better understand whereas the in-service teachers tried to infer contextual evidences to reflect their opinion about scenarios. Finally, contrary to Magnusson et al.'s (1999) nine STO scenarios, they found that the teachers had multiple STO and they did not classify the teachers in a specific scenario.

In 2005, Friedrichsen and Dana extended their previous study to construct a substantive-level theory of the teachers' STO because they believed that Magnusson et al.'s nine scenarios have weak empirical evidence. In this respect, they reexamined the teachers STO in detailed and they worked with four biology teachers in a high school context. They constructed a set of 20 scenarios including high school goals and purposes, objectives, materials, instructional and assessment strategies.

Regarding the results of study, they stated four assertions about the nature of STO. First assertion was that STO has complex in nature, which can be explained by central and peripheral goals and purposes. Central goals and purposes can be seen in the teachers' decision making process whereas peripheral goals and purposes represent the complexity of the participant STO. All teachers reflected STO as the peripheral goals and purposes. STO was also course specific. The second assertion was that the participants' STO had affective domain goals including emotional and motivational factors, general schooling goals including preparation of university or gaining daily life skills, and subject matter goals. The third assertion was that teachers' STO was affected by external factors arising from the out of school activities. In their study, three participant teachers had engaged in nonteaching works and those experiences shaped their STO. On the other hand, the participant teachers did not engage in any educational conferences, activities or collaboration, which enhance professional development. The last assertion was related to school context which had a major effect and shaped the teachers' STO. All these contextual factors such as students and their feedback about the instructions, teachers' beliefs, and time concern about the application of students-centered activities shaped the participants' STO.

After Friedrichsen and Dana's (2003; 2005) works on STO using empirical evidence, Friedrichsen, van Driel, and Abell (2011) had a closer look at STO again in order to clarify the definition of STO and provide the science educators with construct of STO. In the literature there are two definitions of STO. First one was offered by Anderson and Smith (1987) and they defined it as "general patterns of thought and behavior related to science teaching and learning" (p. 99). The second definition was offered by Magnusson et al. (1999) as "knowledge and beliefs about the purposes and goals for teaching science at a particular grade level" (p. 97). In this respect, some researches included misapplying of definition of STO or some researchers interpreted STO inappropriate way. For example, Anderson and Smith's definition was considered as a model or framework in a particular study; however, the researchers used Magnusson et al.'s (1999) definition to interpret the data results. Friedrichsen et al. (2011) investigated 63 papers aiming to portray STO and citing

Magnusson et al.'s (1999) definition. According to the results of 63 papers, STO was used various ways or uncertain way. There was also no empirical evidence between STO and other components. Moreover, STO was considered as one of the nine orientations. The studies conducted by Friedrichsen and Dana (2003; 2005) showed that teachers' STO was not categorized in one scenario, and the teachers can have and present different characteristics from each scenario. According to the Friedrichsen et al.'s (2011) results, they offered a consensus about STO including three characteristics; "beliefs about the goals or purposes of science teaching, the nature of science, and science teaching and learning" (p.373). As a result, STO studies should include the three dimensions and nine categories should be reconsidered.

In order to check the validity of Friedrichsen et al.'s (2011) framework, Boesdorfer and Lorsbach (2014) conducted a study to discover that the framework can be used as a useful tool in STO research. The research involved a case study including a chemistry teacher who has 11 years teaching experiences. The study context had teaching practice reform based on performance and inquiry. Semi-structured interviews, classroom observations, and teaching documents were employed to collect the data of study. According to the results of this study, participant teacher's goals and purposes for science teaching was to enhance the students' problem solving ability by using materials, knowledge. The teacher used summative assessment technique. On the other hand, the participant teacher had a facilitator role when analyzing knowledge about science teaching and learning. When looking at the participant real teaching practices, she applied guided-inquiry activities. The students engaged in solving a problem by using science process skills. To sum up, the teachers' decision making process and teaching practices were aligned with her STO. She also had constructivist teaching and learning views, namely, the students should be built new knowledge on the previous knowledge. Lecturing was never used by the teacher but some class discussion was conducted, in which the students were engaged in actively. She did not use any NOS goals and purposes in her planning and teaching activities. The researchers stated that Friedrichsen 2011 framework was more appropriate for conducting STO studies.

However, similar to Magnusson et al.'s (1999) view, the participant teacher's STO affected the other components. The participant teacher reflected a STO which is desired classroom context including students-centered applications, performance assessment, and community centered. However, she did not provide her students with high-order thinking works. The students could only reach knowledge, comprehension and application level in the Bloom's Taxonomy.

Another study was conducted by Ramnarain and Schuster (2014) to portray the differences physical sciences teachers' STO between the teachers in township and in suburban. This study differed from previous studies in terms of both methodological and theoretical frameworks. Four central orientations; didactic direct, active direct, guided inquiry, and open inquiry were used as framework arising from Ausubel's Theoretical Framework. The authors used mix methods technique. In quantitative phase, "the pedagogy of science teaching test (POSTT (Cobern et al., 2010; Schuster et al., 2007, as cited in Ramnarain & Schuster, 2014))" was used and included ten pedagogical vignettes. The participants were 44 from township and 47 from suburban 12th grade high school teachers. In qualitative phase of the study included interviews conducted with five townships and five suburban school teachers. According to the results of POSTT instrument including an orientation range, such as didactic is 1 point, active direct is 2 points, guided inquiry is 3, and open inquiry is 4, there was a significant difference between township school teachers' orientation (M=2.1, SD=0.77, which represents active direct) and suburban teachers' orientation (M=3.1, SD=0.67 which represents guided inquiry). Moreover, the qualitative evidence explained the difference between township school teachers' orientation and suburban teachers' orientation. School context was a major factor for the pedagogical preference of teachers such as class size, accessibility of resources and materials, culture of the schools, parents' involvement. Characteristics of the township schools such as large class sizes and inadequate materials and resources hinder the application of inquiry activities whereas suburban school context had more opportunity than township schools. Finally, township schools showed poor performance on national exams so the parental involvement affect the teacher STO, and the teachers presented teachers centered activities in order to increase the performance in national science exam.

Another STO study was recently conducted by Campbell, Melville, and Goodwin (2017) to explore if the resource activation model of cognition explains the teacher's STO and topic-specific PCK. The authors adopted STO model offered by Friedrichsen et al. (2011) as well as theoretical framework named "resource activation model of cognition" (Hammer, Elby, Scherr, & Redish, 2005, as cited in Campbell et al., 2017) because they believed that previous models have not been enough to clarify teachers' STO and their classroom applications. The data collection tools were comprised of three interviews, and class observations of two topics. The participant teacher worked with the ninth grade high school while teaching earth science topics. The results of the current study showed that STO might derive from topics-specific and different activation of resources. The participant teacher reflected standards-based reform orientation but the degree of reform level could be changed from the topic to topic. For example, the oceanography topic had more traditional characteristic than the teaching of the pollution topics in which the teacher reflected reformed based teaching orientation. The teacher reflected standards-based reform teacher orientation profile and there was a relationship between teacher's interview data and his real teaching practices. Reformed based beliefs were considered by the teacher in order to enhance students' meaningful learning. Thus, students should be engaged in activities where they were able to construct their own knowledge claims. Moreover, in the topic of pollution, the teacher engaged the students in discussion environment about pollutions. Then, students were allowed in a process where they selected correct and appropriate filtration systems and they designed their filtration system. In this teaching example, the teacher reflected a consistency between her beliefs and teaching practices. However, teaching sub-topics of oceanography, there was a mismatch between the teacher beliefs and his teaching. The teacher used generally didactic teaching during the topics and the teaching was not aligned with the reform based STO. According to the framework of the study "resource activation model of cognition", it can be explained that different epistemic resources were used by the teacher while teaching of different topics, which led to inconsistencies between the teacher beliefs and his applications in cognitive states.

After looking the place of STO in PCK, KoA is another component investigated to find out the relationships between KoA and PCK. A study was conducted by Falk (2012) so as to examine the effect of formative assessment on teachers' PCK, and which components were used and built while teachers perform assessment practices. In the study, the combination of two conceptualizing frameworks was used a model offered by Herman, Osmundson, Ayala, Schneider, and Timms, (2006) for conceptualizing of assessment, and Magnusson et al.'s (1999) PCK model for conceptualizing of PCK. In order to conduct study, professional development for formative assessment context was designed for eight weeks' period to enhance teachers' knowledge and practice with electric circuits unit in fourth-grade elementary level. The participant of the study involved 11 fourth grade elementary teachers who had teaching experiences ranging from 3 to 26 years but they did not have enough experience teaching of electric circuits. The multiple data collection tools were used ranging from teachers works; video records of professional development sessions, materials, posters to students' works. According to the results, two pedagogical events appeared; teachers used their PCK components such as KoC, KoIS, and KoL, and the components such as KoL, KoC, and KoA were enhanced during formative assessment process. When looking at usage of PCK components, teachers employed KoC including sub-components of knowledge of learning goals and knowledge of local curriculum in formative assessment. KoIS was often utilized in formative assessment process. When teachers monitored the students' performance, instructional strategies such as activities and representations were employed to design instruction based on students' works, to make inferences what was the effects of prior instructions on students' works, and to judge to determine how well instructional strategies compatible with specific assessment. Moreover, KoL was used by the teachers to interpret common students' errors and students' alternative conceptions. On the other hand, this study provided teachers with development of PCK. Each assessment process was enhanced to build PCK components; KoL was constructed by interpreting students' responses, KoC was built by the teachers to express curriculum goals, and KoA was developed through teachers' evaluating and reviewing assessment tasks. To sum up, participant teachers were engaged in professional development in formative assessment, and they used actively PCK components of KoC, KoIS, and KoL. However, there was no evidence for usage of KoA and STO. The effects of two components did not appear in the formative assessment process. On the other hand, while teachers engaged in professional development, KoC, KoL, and KoA were newly constructed by the teachers however, STO and KoIS were not affected by the formative assessment.

Teachers teaching practices provide substantial and valuable evidence about teachers PCK. In this respect, Chan and Yung (2015) investigated teachers PCK development in classroom context in order to discover possible factors which support PCK development. They used case study methodology in an exploratory nature and had four science teachers having experience from 6 to 22 years. The study was designed in the curriculum change context in which the participant teachers would teach a new topic including from frontier science to polymerase chain reaction in new senior secondary biology curriculum. In this context, the teachers were expected to have minimal PCK and during teaching new topic, the participant teachers might discover possible new instructional strategies or presentations. Therefore, the data collection tools were comprised of interviews, classroom observations, field notes, and teacher/students works. The authors used post interviews after class teaching as a primary data collection tool because the aim of the study focused on the development of teachers PCK in teaching process which was called on-site PCK development (Chan & Yung, 2015). Authors used Magnusson et al.'s (1999) PCK model as framework for analyzing the data and focused on only four components (KoL, KoIS, KoC, and KoA) in their study. According to the results of the study, on-site PCK development was supported by three factors as trigger. First one was unexpected students' responses. This stimulus provided the teachers with modification related to instructional strategies to response the students' failure. The teachers first used KoL to determine students' prior knowledge about related topics, then they had to change instructional strategies such as a new analogy "the replication of bacteria (individually, cannot be seen by the naked eye to form bacteria colonies (which can then be seen by the naked eye)" (Chan & Yung, 2015, p.1256). In this stimulus, it can be seen that KoL had an effect on KoIS and helped the development of teachers' PCK. The second factor was environmental stimulus for development on-site PCK. An example of this stimulus was seen during teaching of polymerase. When the teacher wrote the word "polymerase" on the blackboard, some students had learning difficulties about the meaning of polymerase. Because the students had prior knowledge about polymerase, they had known polymerase as polymer and monomer which are translated to primers in the Chinese. Thus, there was a learning difficulties arising from Chinese word so the teacher handled these difficulties by changing instructional strategy. The last stimulus was related to unanticipated student questions. While teaching topics, the teachers faced so many questions. Some of them lead to pedagogical difficulties for the teachers, and teachers had to change their instructional strategies. An example was seen while teaching of DNA loading dye. One student asked a question "as the dye should have no charge, why can it move?" (Chan & Yung, 2015, p. 1260). Then, the teacher realized that the student had misconception "dye used in the analysis of PCR products should have no charge" (p.1260) and so as to handle this misconception, the teacher changed instructional strategies. To sum up, Chan and Yung (2015) focused on teachers' real teaching process in order to clarify PCK development. According to the data, they offered a model about on-site PCK development as illustrated in Figure 2.7.

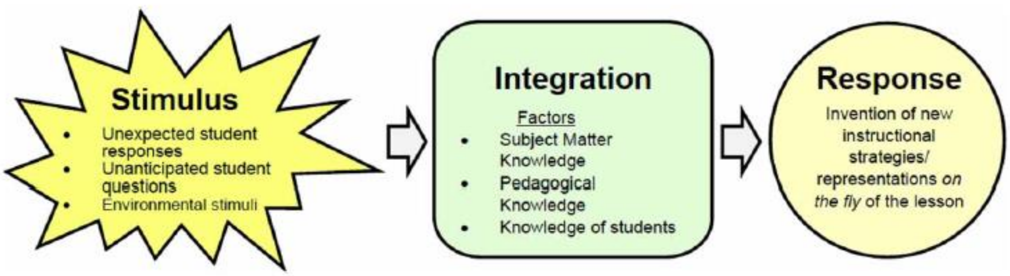


Figure 2.7. The Model of On-Site PCK Development (Chan & Yung, 2015, p.1266)

According to the model, stimuli played an important role to start teachers PCK development. In this process, teachers' KoL worked an active role in order to realize students' learning difficulties, misconceptions or lack of students' prior knowledge. After recognizing unexpected situation, teachers tried to determine what the resources of learning difficulties were by using their SMK, PK, or KoL. Finally, they overcome the learning difficulties by changing from previous instructional strategies to a specific one. The modification of KoIS meant on-site PCK development, the interaction between KoL and KoIS was also seen explicitly in this study.

Until now in this part, previous studies investigated teachers' PCK in terms of one or two components. Contrary to previous studies, Loughran et al. (2004) tried to explain teachers' PCK in different way. They engaged in a longitudinal research project in which PCK was considered in the theoretical view, and understood, reported, and interpreted the knowledge of science teachers' teachings in specific purposes. According to authors, traditional techniques or methods are not enough to understand the teachers PCK. For example, Shulman's model including many knowledge bases (SMK, PK, PCK) is not enough to define teachers real teaching (Loughran et al., 2004). In this respect, they designed a project lasted two years and 50 high school teachers participated in. The teachers were asked to document their "Pedagogical and Professional Experience Repertoires (PaP-eRs)" and then, to fill out "Content Presentation (CoRe)". The aim of this process was that teachers engaged in a process where they talked about their decision making and teaching process, namely, their topic-specific PCK. CoRe including two parts (as illustrated in Appendix B), in vertical part, there were eight questions about big ideas selected by teachers. On the horizontal part, teachers wrote big ideas which were concepts, phrases, or sentences across the content area. Giving answer of eight questions provided teachers with expressing of their presentations. On the other hand, PaP-eRs tried to unpack effective classroom practice, in other words, it is "a window into a teaching/learning situation wherein it is the content that shapes the pedagogy" (Loughran et al., 2004, p.377). PaP-eRs offered teachers opinion about classroom action so it was not enough to pose the complexity of PCK. With this in mind, the authors linked teachers' PaP-eRs and CoRe in order to better understand. To sum up, two research tools were developed to uncover and analyze science teachers PCK.

Bertram and Loughran (2012) conducted a study which derived from a longitudinal project during two years. The researchers tried to investigate how CoRe and PaP-eRs might influence on science teachers' knowledge and practice, and how the teachers might construct PCK as part of value. Authors designed the study based on CoRe and PaP-eR framework, and they supported to their data with interview based approach. In this respect, qualitative methodology was used in an ethnographic nature. Six teachers were engaged in this study to analyze their PCK development. Three teachers were working in middle school science from 7^{th} to 10^{th} grade, one teacher worked as a senior specialist teaching from 11^{th} to 12^{th} grade physics, other two teachers were working at primary school. The teaching experiences of the participants varied from three to 25 years (expect for one teacher had only six mouth teaching experience). The participant teachers selected a topic (space, interactions of light and matter, and genetics) in order to design their own CoRe. The results showed that the participants did not have sophisticated knowledge to construct their PCK at the beginning of the project. After, the introduction of PCK was offered all participants, and then, CoRe and PaP-eR were taught. The belief was generated all the teachers that CoRe was useful tool to prepare lesson planning and to reflect this plan in practice, and CoRe questions also provided the teachers with deeper thinking big ideas and students background. Similar to contributing of CoRe, the participants reflected positive views about PaP-eR which was a reflection tool after teaching, and shaped their teaching. To sum up, CoRe and PaP-eR increased the participants' awareness about their own PCK and students' characteristics. However, the teachers believed that designing CoRe and PaP-eR require having free times and they wondered that applying them over curriculum was not applicable. PaP-eR provided the teachers to better understand their PCK in three ways; "professional practice, limiting factors, and their relationships with PCK" (Bertram & Loughran, 2012, p.1038). The development of professional practice included rethinking teaching practices, thinking explicitly teaching and learning, considering important things for students learning. As a result, the teachers assessed their previous teaching practice and they could infer related to next teaching practices.

Another study was conducted by Lee and Luft (2008) to investigate the construct of PCK in a context with experienced secondary science teachers. Researchers tried to determine PCK components and elements, and how these components are organized by the teachers. The study was a case study in qualitative nature, and the participants consisted of 4 high school science teachers who had experience more than ten years and more than 3 years as mentor meaning that beginning science teachers participated in classroom setting where mentor teachers helped them enhance their professional development. Data collection tools included interviews, classroom observations, lesson plans, and teaching reflections of teachers monthly. The results of the study showed that seven essential components arose from participant teachers. The first one was knowledge of science. All participants believed that strong SMK was very important for science teaching, and their knowledge was continually increased on time. The second component was knowledge of goals. All teacher designed lessons based on their goals, and a common goal was to construct the relationships between natural phenomena and everyday life. The knowledge of goals also shaped their teaching practices, similar to Magnusson et al.'s (1999) STO shaping other PCK components. The third component was KoL. All the teachers had knowledge about students' learning approaches, their activities, and their lives outside of school. The interaction between teachers and students provided to acquire KoL, in other words, the classroom experience enhanced the teachers' knowledge. The fourth component was knowledge of curriculum organization. According to the teachers, this knowledge was a tool linking the other knowledge bases such as subject matter, and other subjects. Moreover, the curriculum required to be designed in a flexible manner so as to overcome unpredictable situations. The fifth component was knowledge of teaching. The knowledge helped teachers design and modify their lesson plans based on taking feedback students learning. This knowledge was also affected by knowledge of goals. The sixth component was KoA. Assessment played crucial role in the teachers teaching because it provided to get feedback about students learning performance and to determine that the curriculum and instruction have an effect on students understanding related concepts. The last component was knowledge of resources.

The resources included materials in and outside of school. Teachers believed that local facilities or external materials shape their goals and instructions. The teacher generally engaged in outside of school activities to discover scientific phenomena. To sum up, the researcher tried to determine teachers PCK from their reflections, and seven common PCK components appeared in all the teachers teaching. The seven components had different characteristics form other conceptualizing because the teachers identified their conceptualizing of PCK. Moreover, this study engaged the teachers in conceptualizing process, similar to Loughran et al.'s (2004) study, and the teachers' views about PCK and components differed from other models.

Similar to previous studies, researchers focused on enhancing teachers PCK. In doing so, Goodnough and Hung (2009) designed an implementation including problem based learning (PBL) in order to analyze teachers PCK and monitor the development of their PCK. The participants of this study were five K-6 teachers (elementary level) who taught all subjects. One teacher worked with first grade students, and she was responsible for teaching the model of PBL on "the need of living things". Another teacher worked with second grade students and was responsible for teaching model on "life cycles", one teacher worked with third grade students and was teaching the model on "the need of living things". Another two teachers worked with fourth grade students and were responsible for teaching the model of PBL on "habitat". The models of PBL were designed and applied by teachers during six weeks' periods. The data were collected through videotaped sessions done by teachers their own teaching, pre-post interviews, planning and debriefing meeting, teachers' journals entries, and documents and materials. The authors explained the results of the study in 5 parts; STO, KoC, KoL, KoA, and KoIS. First component was STO, and in this component, teachers' beliefs about teaching and learning of PBL mismatched with real classroom teaching. Although the teachers planned to apply student-centered application based on the nature of PBL, they continued to teach related concepts in traditional ways. During project, they challenged to transfer their beliefs to classroom practices, so they also discovered the difficulties of those transfers. Regarding the component of KoC, after implementations of PBL, the teachers gained some abilities and knowledge in terms of KoC. They recognized curriculum goals and outcomes, and they also discovered alternative resources. While planning the PBL units, the teachers learned how curriculum outcomes to be integrated in planning process. As they did so, the nine step of PBL process including detail thinking manner for each step enhanced the teachers KoC. Another development appeared in interpreting learning outcomes. This in-depth planning process provided teachers with interpreting learning outcomes by designing concept maps involving subject matter, skills, outcomes which were targeted in the PBL. With this component of KoL, teachers experienced to deal with students' prerequisite knowledge, abilities, misconceptions, and skills which were required for applying PBL. They also learned how students' ideas were enhanced. Their students engaged in activities in high motivations, and the teachers compared and contrasted PBL activities with previous classes so they were very surprised at the changes that were happening in the students' learning. As for KoA component, PBL having authentic assessment techniques enhanced the teachers' KoA because they designed and applied so many assessment tools such as journal entries, portfolios, group reflection sheets, story writing, presentations, creating models, and rubrics. The teachers had experience to evaluate students' conceptual understanding and problem solving skills. Moreover, students' self-assessment performance attracted the teachers' attentions. On the other hand, the teachers witnessed the application of particular instructional strategies on PBL process, and they inferred the specific instructional strategies could be applied in general science classes. However, during PBL planning process, they selected direct instruction but group working or using models helped to enrich their instructional repertories. To sum up, the elementary teachers had an experience on a new teaching approach. Before the project, each teacher had different knowledge and skills, and they enhanced their PCK by engaging in active learning environment, higher-order thinking, and building individual and students' knowledge.

Aydın, Friedrichsen, Boz, and Hanuscin (2014) conducted a study in order to document teachers PCK and its components in specific topics. Authors compared and contrasted the teachers' knowledge bases to better understand the differences between chemistry topics of electrochemical cells and nuclear reactions. Magnusson et al.'s (1999) PCK model was modified based on related literature and used as theoretical framework. Moreover, similar to other studies, the methodology of this study involved a case study in a qualitative nature. The context of the study included a case in which two teachers were working at same private high school and they were teaching two topics such as electrochemical cells and nuclear reactions. Authors used multiple data collection tools such as card-sorting activities, CoRe, interviews, observations, and field notes including students' and teachers' works. According to the results, two teachers' teaching practices were highlighted in this research rather than their knowledge. Regarding STO, traditional methods were taken placed in their teaching, namely, they reflected didactic STO. On the other hand, some activities such as analogies and demonstrations supported their teaching, and STO moved nearly out of the traditional view. The teachers also believed that students-centered activities were more appropriate for the learning of the topics, and students should discover related concepts in order to gain meaningful understanding. However, because of some factors such as reality of educational system, university entrance exam, or loaded curriculum hindered the transforming teachers' personal beliefs to practice. When teachers' KoIS was examined, authors presented two different knowledge based on the nature of topics. First one was "*content-based and teacher-centered instruction for teaching electrochemical cells*". In this part, the teachers were very active factors, and they used hands-on activities, lab works, or demonstrations but these activities were teacher-centered. Moreover, the participants did not utilize any subject-specific instructional strategies. Rather, they focused on topic-specific instructional strategies. After introduction of conceptual objectives, hands-on activities, lab works, demonstrations were offered in order to provide meaningful understanding and increase the students' motivations. The second teachers' knowledge about instructional strategies was "*less teacher-centered instruction enriched with implicit NOS and STSE in nuclear reactions*". In this part, teachers presented conceptual understanding by using lecturing, similar to electrochemical cells, but some enrichment were engaged in their teaching activities such as relationships between concepts and everyday life, nature of science (NOS), and science, technology, society, and environment (STSE) including discussion about social scientific issues. Another PCK component was KoC. The teachers reflected varied knowledge in this component from electrochemical cells to nuclear reactions, and the teachers had more KoC about electrochemical cells than nuclear reactions. In electrochemical cells topic, each teacher could make relations related topic to other topics and disciplines. The teachers could also change the order of concepts in curriculum, then, presented. In this regard, they had rich knowledge about national curriculum and materials including objectives, limitations, or suggestions. Another PCK component was KoL including students' learning difficulties, misconceptions, and pre-requisite knowledge. When comparing the topics in terms of teachers' KoL, similar to KoC, the teachers had more KoL including students' knowledge and possible misconceptions about electrochemical cells than nuclear reactions. The last component was KoA. On the contrary to other PCK components, teachers applied different assessment techniques but they were subject-specific rather than topic-specific component. The teachers used questioning as informal assessment, quiz, and test as formal assessment, which were not designed for a specific topic in terms of purposes of assessment and methods. Similar to KoC and KoL, the teachers had more coherent KoA about electrochemical cells than nuclear reactions. To sum up, the researchers tried to portray two experience teachers' topic specific PCK based on their components. They found that KoC, KoIS, and KoL were topic-specific in nature whereas STO and KoA were discipline specific. Moreover, Aydın et al. (2014) highlighted that the teachers presented various kind of knowledge and abilities in different topics. These differences arose from the teachers' background such as SMK, national curriculum, or the nature of the topics.

Similar to Aydın et al.'s (2014) study in the Turkish context, Şen (2014) conducted a PCK study including five components to explore three middle school science teachers' PCK and SMK while teaching cell division topic in 8^{th} grade level. He used multiple case studies and collected the data by using pre/post interviews, classroom observations, instrument about NOS, and teacher documents. According to the study results, the teachers had lack of knowledge about both NOS and SMK such as cell cycle, allele gene, independent distribution law, which led the teachers to constitute insufficient connection between meiosis and genetics. When looking at the teachers' PCK results, the teachers had STO including to teach objectives in the science curriculum and to make their students to be ready for high school entrance exam. Moreover, the participants reflected traditional teaching pattern, namely, they had teacher-centered orientation. As regarding KoL component, the teachers had enough knowledge about students' prior knowledge, student's difficulties, and misconceptions. However, they did not effectively handle related misconceptions by using specific strategies. When looking at KoA, the teachers focused on students' conceptual understanding about related concepts by utilizing traditional assessment strategies. They did not assess their students' SPS, NOS, or interdisciplinary subjects. As regarding of KoIS, the teachers generally used lecturing and questioning which were parallel to their STO. Finally, the teachers had strong KoC including objectives, materials, and relationships among related concepts such as cell, reproduction, growth and development. Stated differently, they followed science curriculum to prepare their students on upcoming high school entrance examination. To sum up, Şen (2014) found that the teachers' STO affected other PCK components, which is similar to Magnusson et al.'s (1999) PCK model. Moreover, the teachers' KoC was affected by teachers' experiences, KoL, KoIS, and environmental factors. Finally, the teachers' KoIS were shaped by STO, KoC, and KoL.

In the science teacher education, there are many study focusing teachers PCK and their development since 1986. It is difficult to review all PCK studies and to document for this part. However, a review study might help to summarize PCK studies, and provide us to see general pattern about teachers' education. Schneider and Plasman (2011) searched the science teacher literature in order to better understand which factors enhance teacher knowledge, and which knowledge bases increase. However, authors did not aim how teachers transfer the knowledge to classroom practice. In this respect, the studies published from 1986 to 2010 and including science teachers' learning were searched by using following key words; "pedagogical content knowledge, science teachers, teacher knowledge, knowledge base for teaching, teacher thinking, teacher professional knowledge, teacher expertise, teacher learning, mentors, mentorship, leaders, and leadership" (Schneider & Plasman, 2011, p. 535). Moreover, seven journals and electronical databases were investigated: "Electronic Journal of Science Education, International Journal of Science Education, Journal of Research in Science Teaching, Journal of Science Teacher Education, Research in Science Education, Science Education, and Teaching and Teacher Education" (p.535) and databases "ERIC, Educational Full Text, Educational Research Complete, EBSCOhost, and Academic Search Complete" (p.535). The researchers determined 91 articles matching the above criteria. Each article was analyzed based on PCK models including different frameworks such as Friedrichsen et al. (2011), Magnusson et al. (1999), etc. The results showed that in the science teacher education, there were many studies about pre-service teachers' PCK and few studies for in-service or experience teachers. Five longitudinal studies were determined over 2 or more years. When STO analyses were examined, authors separated STO under three sub-components. First one was teachers' goal and purposes about teaching science. The studies generally including the definition of goals and purposes which were not used consistently, and the research only focused on teachers' goals as objectives. On the other hand, teachers' purposes of science teaching were reflected as "gaining students' attention, then developing students' skills, followed by supporting understanding, and finally focusing both on value and understanding" (p. 541). Moreover, the data results showed that there were differences among teachers why science should be taught. Whereas pre-service teachers' views were organizing students for life and enhancing knowledge and skills for next level schooling, elementary teachers focused on enhancing student' curiosity and engaging students in funny learning environment. On the other hand, secondary teachers aimed students to build confidence and enhance students' awareness of the usefulness of science. Regarding of teachers' primary goal, pre-service teachers focused to teach on conceptual learning while experience teachers focused to take precautions on students' misconceptions as well as conceptual understanding. The second sub-component was NOS. The teachers did not enough knowledge about NOS and they generally did not consider NOS as a goal for teaching science. In other words, understanding and learning of NOS was not developed a notion for science teachers. The last sub-component was the nature of learning science for students. Many teachers believed that teaching could be transferred into students by using lectures, note taking, presentations related materials. However, some teachers explained that students need to read different resources and engage in hands-on activities in order to discover targeted information. Some pre-service teachers believed that students could learn the topics by using auditory learning skills to listen their teachers. Conversely, teachers' views about inquiry teaching were that inquiry was not the best way to provide students' meaningful learning. Teachers' views about learning and teaching science have been affected by their previous education, or experiences. For example, pre-service teachers believed that student-centered activities were most useful tool to provide learning because they were engaging in reform based science methods course. However, they had challenged to practice those activities. On the other hand, experience teachers supported to apply teacher-centered activities because of their teaching experience, except teachers participating reform based curriculum activities, or in-service education. When looking at KoL analysis, in many studies, researchers focused on teachers' knowledge about students' misconceptions, and other sub-components such as students' learning difficulties, or pre-requirements were ignored. Thus, many studies showed that participant teachers did not have enough knowledge about students' thinking about science. This finding was compatible with teachers STO because teachers considered that the learning was a transformation of knowledge, and they believed that students would not have any previous knowledge or idea before learning related concepts. Pre-service teachers had less knowledge and ability about why students believe that learning science concepts are very difficult than experience teachers. If they gained some teaching experience in classroom context, they could be aware of those difficulties. When looking at KoIS analysis, researchers reported only the instructional strategies used by participant teachers; however, they did not explain why the teachers had selected those strategies. Moreover, multiple teachers believed that inquiry was a process in which the students make investigation. In science education, inquiry applications have been taken attention, and there has been an effort to apply inquiry in pre-service education. Thus, pre-service teachers tended to apply as far as possible. However, the reports showed that teachers misused the definition of inquiry, and they enacted inquiry activities with missing parts. For example, hands-on activities, lab works, or discovering any concept were considered as an inquiry application. The teachers applied generally instructional strategies such as "students participating in hands-on activities; reading about science; viewing scientific videos, pictures, or physical models; or hearing descriptions of real-world applications" (p.551). In addition to above examples, discussion and explanations were considered discourse strategies including writing and reading assignments. Discussion was used nearly all reports but the definition was not clear. Moreover, some studies reported students-centered strategies but the teachers did not interpret correctly this definition, and when they applied any activities, they thought that it was student-centered activity. Appling small group activities, KWL chart, students' journals, all activities were reported in the studies as student-centered. When looking at KoC analysis, new teachers did not have enough knowledge about what science concepts in order to design lesson, or what resources could be reached. The teachers were also unfamiliar with scope, sequence, standards, or material in a curriculum. However, this unfamiliar situation was removed by having teaching experience. When looking at KoA analysis, the component of KoA was the most ignored components in the research. Some findings of study showed that pre-service teachers or new teachers did not emphasize the assessment part in their lesson plan, or using informal questions was considered as an assessment. However, some educational supports provided teachers with authentic assessment strategies such as "portfolios, performances, presentations, and journals" (Schneider & Plasman 2011, p.554). Some teachers used test or exams at the end of units. In other words, they considered assessment as summative. Some new teachers were aware of alternative assessments but they did not explain their lesson plan. On the other hand, experienced teachers emphasized that instruction and assessment should be acted parallel so as to monitor students' performance. To sum up, this review study summarized the research findings, and portrayed the current situation of science teachers' knowledge and abilities. Moreover, these findings provided the science teacher education with valuable information about the strengths and weaknesses of science teachers, and this study results will guide the future research aiming to enhance teachers' professional development.

In recent years, Gess-Newsome et al. (2017) conducted a study to investigate the relationships between teachers' knowledge bases and the model of teacher professional knowledge. Researchers focused on three teacher's knowledge; academic content knowledge (ACK), general pedagogical knowledge (GenPK), and PCK. They designed a project including educative instructional materials where teachers engaged in inquiry based learning. A total of 50 high school biology teachers were chosen to engage in professional development. The intervention included educative curriculum materials comprising of two biology curricula such as "Insights in Biology" and "A Human Approach" and each curriculum had similar content: "cell biology, heredity, interdependence, evolution, and matter, energy and organization" (Gess-Newsome et al., 2017, p.5). A mix method was used to collect the data. ACK was measured by Major Field Test in Biology (MFTB), and students' achievement test was also used to evaluate students' performance. In order to determine teachers GenPK, the Reformed Teaching Observation Protocol (RTOP) was used. In order to measure PCK, three constructs were determined; PCK-CK (content knowledge), PCK-PK (pedagogical knowledge), and PCK-CxK (contextual knowledge). They were measured by Project PRIME PCK Reflection Instrument, and the Project PRIME PCK Rubric. Students' achievement was measured with a test including 5 topics and each topic has 20 items. Finally, teachers' interviews were used to support quantitative data. According to the data analyses, researchers tried to measure PCK by using a tool including written reflections, interview reflections, and video recorded classroom observations. Based on data results, PCK was comprised of two constructs such as PCK-CK and PCK-PK. In other words, the teachers' topic-specific content and applications were explained at least two factors. When looking at the effectiveness of the project, the intervention of educational curriculum materials had a significant effect on teachers' knowledge and skills. Regarding students' achievement, there was a significant change in favor of post-test [$t(4717)=58.39$, $p< .001$]. Moreover, teachers' ACK, GenPK, PCK-CK, PCK-PK, and teaching practice were increased at the end of the project. These quantitative results were also supported by qualitative data. In order to validate the model of teacher professional knowledge, researchers conducted correlation analyses based on teachers' knowledge bases. According to the results, ACK was correlated to PCK-CK, and PCK-CK was correlated to GenPK. However, PCK-CK was moderately related to PCK-PK. Moreover, a significant correlation appeared between GenPK and classroom practice. The last step their analyses were to determine how teachers' knowledge and practice influence to students' achievements. According to the data results, only teachers' ACK had significant effect on students' achievement. Other knowledge bases such as PCK-CK, GenPK, and PCK-PK did not provide any evidence to support students learning. In other words, having strong PCK is not an indicator for the increasing students' achievement. Another aim of the study was to validate the theoretical path of study arising from the model of teacher professional knowledge and skill (Gess-Newsome, 2015), and so the results did not validate the effects of teacher practice and knowledge on students' achievement, except for ACK significantly explained students' achievement.

Another current study was conducted by Melo, Cañada, and Mellado (2017) to construct the development of PCK of two physics teachers and to determine the relationships between the emotions and teachers PCK. The participant teachers were working at high school with students' ages from 17 to 19. The researchers designed a project including an innovation of electric fields topics to assume that affective domain and teachers' knowledge bases unpack the transformation and integration of PCK into project. In this study, Alonzo and Kim's (2016) PCK definition was used. They characterized PCK in three steps such as declarative, design, and action. The authors assumed that one factor is emotions might affect teaching and learning, and emotions effects should be investigated as well as cognitive factors. Within this minds, the authors aim was to define two physics teachers' PCK and to conceptualize the emotions' effect on teachers PCK while the teachers were engaging in an innovation project. In order to collect the data, semi-structured interview, open-ended questionnaire, and CoRe were employed. Open-ended questionnaire was used to determine teachers' decision making process in terms of instructional strategies and to obtain their think about curricular design. The data was analyzed based on four

PCK components such as KoC, KoL, KoIS, and KoA. Each component was categorized in three group tendencies such as teacher-centered tendency, student-centered tendency, and intermediate tendency in which teachers presented knowledge and skills somewhat closer both teacher-centered or student-centered. According to the data results, the project provided the teachers with development of their PCK. For one teacher, KoIS and KoC were subjected to the biggest progression from teacher-centered tendency to mixed tendency. This teacher did not have a change on KoA. Other teacher was less successful in PCK progression than previous teacher. KoC including objectives, and KoL including learning difficulties and reasons were subjected to innovation. However, KoA was changed from constructive tendency to teacher-centered tendency. For one teacher, the resources of emotions arose from the curriculum, the content, the pupils, and the context. The content factor provided the teacher with positive emotions such as satisfaction, capability, security, and confidence deriving from the teacher's content knowledge, and her successful application of lab work and experimental activity. On the other hand, the teacher had negative emotion such as frustration and anxiety related to mathematical challenges to use for physics, and the teacher had experience the emotions from university years. After project two years later, the emotions related to KoC and KoIS did not show significant changes because the modification of content and presentation based on project aims led to increase both satisfaction and concern. Moreover, student-centered application and evaluation caused to teacher to feel anxiety, disappointment, and frustration while applying those activities. Other teacher reflected similar feeling during the project. KoC, KoIS, SMK, the relationships with the students, and the context were main resources for positive and negative emotions. For this teacher, the topic of electric charge and electrification phenomena provided the teacher with positive feeling. However, some topics were considered by the student as boring, which led to teacher to feel negative emotions such as pessimism, disappointment, and boredom. However, in the second year of project, there were some changes such as increasing positive emotions, and decreasing negative emotions. On the other hands, the relationships between students and teacher in physics lab caused the classroom management problems, which was reflected a negative emotion.

Regarding the relationship between emotions and content, one teacher had positive emotion during the first year of project but the second year of project, both positive and negative emotions appeared especially in the topics of electric field lines, electrostatics and electro kinetic. On the other hands, the other teacher was subjected to slightly emotional change from first to second year. He experienced a negative emotion about electric force, superposition of the electric field, and the difference between field and force. However, he gained a new presentation skill about topics, then, this modification provided the teacher to feel more positive emotions except for lines of force topic. To sum up, during the project, the teachers PCK were developed gradually, and some components were enhanced (not all of them). The teachers' tendency about teaching of electric field was categorized on three phases such as teacher-centered, intermediate, and innovative. Similar to teachers STO, a component of PCK, which was not considered in this research, the researchers had difficulties to label a teacher teaching tendency as student-centered or traditional because each category included mix or more than two tendencies. Moreover, as Gess-Newsome (2015) mentioned amplifiers and filters, the effects of emotions acted both amplifiers and filters in the teachers' decision making process and practicing. In other words, the negative or positive emotions shaped the teachers' PCK similar to the beliefs in STO.

To sum up, science teacher PCK studies have a tendency to enhance teachers' professional development (Bertram & Loughran 2012; Gess-Newsome et al., 2017; Goodnough & Hung, 2009; Melo et al., 2017) though longitudinal project, and researchers have tried to collect evidence to validate PCK models or frameworks (Boesdorfer & Lorsbach, 2014; Newsome et al., 2017; Melo et al., 2017) though using different methodologies and engaging different variables to gain better understanding science teachers' PCK.

2.3 The Studies about the Interaction of Science Teachers' PCK Components

Science teaching and learning are complex process, thus many knowledge act together to transfer knowledge to students. Researchers have emphasized that the teacher knowledge bases should be considered together. Shulman (1986) defined that knowledge bases and separated seven categories but other researchers following his framework did not isolate knowledge bases prominently (Grossman, 1990, Marks, 1990). Cochran et al. (1991) defined PCK as pedagogical content knowing in accordance with the constructivist approach and they utilized four knowledge bases "knowledge of environmental context, knowledge of pedagogy, knowledge of students, and knowledge of subject matter" (p.23) in their model. The knowledge bases are combined and interrelated when teaching is employed but cannot be separated. Pre-service teachers can combine the knowledge bases slightly or fragmented whereas experience teachers can present more strong interrelation. On the other hand, this combination might occur more dominant among two or three knowledge bases. For example, classroom observations for pre-service teacher enhance the knowledge of school context, or the teacher engages in teaching experience on difficult concept first can enhance SMK and knowledge of learners (Cochran et al., 1991). If the teacher faces the similar context, he will combine and integrated these knowledge bases to generate his PCK.

After Cochran et al.'s (1991) work emphasizing the integration of knowledge bases, the relationships among teachers' knowledge bases were considered by other researchers. One example appeared in Fernandez-Balboa and Stiehl's (1995) work. They investigated 13 university professors' PCK presented in several disciplines, and aim of the study was how professors conceptualize and practice their PCK. Grossman's (1990) PCK framework was used to design their study, and semi-structured interviews were employed to understand participants' PCK. Regarding data results, four knowledge bases appeared in clearly in the data similar to Grossman's (1990) definition, and additional one component was coded as participant purposes for teaching including professors' belief system. Moreover, the authors recognized that the participants used those knowledge bases in a collective way. Successful teaching and learning appeared only the integration of PCK components. In other words, PCK components did not act independently. One teaching behavior appeared when the participants organized at least two components actively. For example, students' learning difficulties was handled by considering knowledge of the characteristic of students or students' prior knowledge. In this respect, participant professors should have organized the most appropriate instructional strategies in a correct time. In doing so, the integration of components was most important teaching behavior for meaningful learning. Finally, combination of PCK components did not act in a linear process because various factors or beliefs might affect the integration of components simultaneously.

Magnusson et al. (1999) reflected a similar view about integration of PCK components. They defined that PCK is a transformation of multiple knowledge in teaching a specific concept, namely, components act as a whole. Deficiency or misusages of any component, or problems between two components lead to become problematic situations when developing and applying those components. In other words, focusing on the development of a component might not be enough to present targeted behaviors or teaching. Therefore, the interactions of components are very crucial to understand of PCK construct, and they appear in complex situations. In this respect, it is very important how components interact together and how they affect science teaching.

Regarding the suggestions of investigating of the interaction of PCK component, an empirical evidence was offered by Henze et al. (2008) in order to investigate the development of PCK in nine experienced science teachers engaging in new syllabus in which the teachers was teaching the first few years on the topic "Models of the Solar System and the Universe". The data were collected by semi-structured interviews during three semesters. The researchers focused on four components such as KoIS, KoL, KoA, and knowledge about goals and objectives of the topic in the curriculum. Results showed that two types of PCK development appeared from teachers' knowledge and practices as illustrated in Figure 2.8.

According to the Figure 2.8, development of teachers' PCK were categorized in two groups such as Type A including teacher-centered tendency and Type B including more or less student-centered tendency. In Type A category, teachers' goals and objectives of teaching increased the development of knowledge of instructional strategies, namely, it effected instruction. Similarly, knowledge of students understanding also affected the teachers' instructions. Development of KoL component arose from KoA. The teachers took feedback from students' performance and written test and group reports. Finally, teachers' instructions supported the development KoA. On the other hands, in Type B category, there were three mutually relationships among development of KoIS, KoL, and KoA. The goals and objectives component did not change over time significantly. Similar to Type A, KoIS consistent with the teacher goals and objectives enhancing KoIS. Moreover, KoL also supported the instructional strategies. The development of KoL component was prompted by KoA and KoIS. On the other hand, development of KoA arose from KoIS (similar to Type A) and KoL. As a result, the three mutually interactions referred that Type B of PCK has dynamic interaction whereas Type A of PCK have static interaction. In this study, the relationships among PCK components were explained in teachers' professional development process based on four components. However, STO and KoC were combined in the "knowledge about goals and objectives of the topic in the curriculum", and it is not clear the effects of STO or KoC on teachers' professional development process separately.

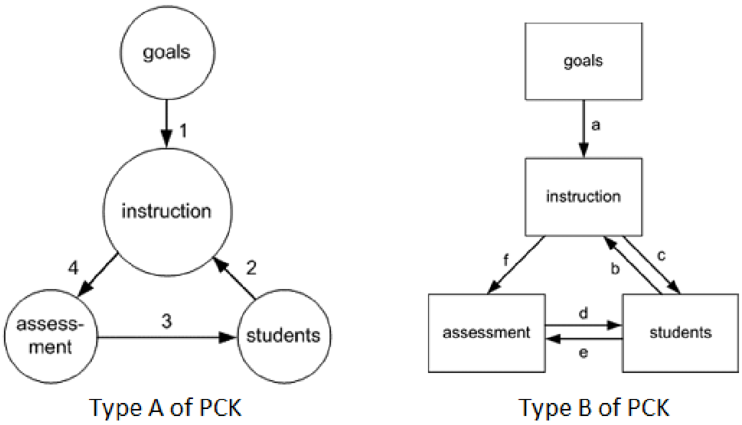


Figure 2.8. Development of Teacher PCK Components

Another evidence based research was conducted by Kaya (2009) to determine the relationships PCK components and SMK while teaching ozone layer depletion. The participants were 216 pre-service science teachers who were in final years in their undergraduate program. The data were collected by an open ended survey so as to evaluate the participants' SMK and then, semi-structured interview was conducted with 75 pre-service teachers to determine the participants' PCK. The mixed method was employed, and qualitative technique provided to categorize the participants' both SMK and PCK. The quantitative methods "Pearson product-moment correlation coefficient and Multivariate analysis of variance" were used to determine the relationships among knowledge bases. According to the results, 46% of participants had low level or naive SMK, 24% of them reflected plausible knowledge, and 28% of them had appropriate SMK. Regarding PCK results, the participant teachers reflected plausible knowledge level based on four PCK components. When looking at results in detail, 24% of participants had naïve KoC, 27% of them reflected naïve both KoL and KoIS, and 38% of them had naive KoA. In other words, the participants did not reflect enough knowledge both SMK and PCK in terms of the teaching of ozone layer depletion. Moreover, when looking at the relationships among knowledge bases, participants' SMK had significant relation with the participants' PCK, and all components except for KoA. On the other hand, KoA did not connect other components significantly but there were significant and moderate relationships among other three components. According to the MANOVA results, PCK and its components were significantly varied among the ability groups such as appropriate, plausible, and naïve. To sum up, Kaya (2009) reached the conclusion that participant teachers did not have enough knowledge and ability to teach the topic of ozone layer depletion. But their knowledge bases were in significant relations. In this study, STO was not considered to analyze to determine the components' relations similar to Henze's (2008) work.

Another study related to interaction of teachers' knowledge bases was conducted by Friedrichsen et al. (2009). Researchers examined the effect of the role of teaching experience on teachers' professional development. They designed an alternative certification program in order to observe teachers' knowledge development. They used Shulman's (1986) framework and selected four biology teachers participating same teacher education program. However, two of them had teaching experience with K-16 students and other of them did not any teaching experience. They used qualitative-interpretive research design so as to elicit the effectiveness of teaching experience on participants' PCK development. They also used lesson preparation method including lesson plans and interviews to obtain data from participant teachers. According to the data analysis, they defined two assertions. Assertion 1 reflected that the teachers in both groups used their general pedagogical knowledge, in other words, they could not rely on PCK in their lesson plans. When looking at the development of each PCK component, all teachers reflected didactic STO over the alternative certification program. As KoL component, both teacher group were aware of students had prior experience or learning difficulties about scientific phenomena but they did not give a specific example to reflect their knowledge about students' prior experience or learning difficulties. Some differences between two groups were detected in their KoC. Experience teacher enriched the knowledge of curriculum with district and state goals and purposes but the intern teachers considered the curriculum with textbook. When looking at the last component of assessment, there was similar pattern for both experts and interns. Neither experts nor interns indicated any assessment activities in their lesson plans. They considered assessment as to monitor students during lessons and to grade students' worksheets. On the other hand, assertion 2 focused the knowledge bases in terms of both experts and interns. The researchers summarized the results on two figures such as Figure 2.9 based on the interactions of expert teacher knowledge bases, and Figure 2.10 based on intern teachers' knowledge bases.

The figures showed that STO "didactic" hindered the development of other components, thus the researchers used STO as a filter in both expert and intern groups. The differences between expert and interns' groups appeared on interaction among components. In this regard, Figure 2.9 showed that the expert teachers' engaged in the interactions among KoL, KoA, and KoC components while development of their PCK. However, KoIS interplayed few times with other components, thus the researchers did not draw KoIS as overlapping circles with other components. In other words, the overlapping circles engaging in KoL, KoC, and KoA indicated that there were many interactions among pedagogical knowledge components while development PCK process. As a result, SMK and pedagogical knowledge and its components helped the development the expert teachers' topic specific PCK for heritable variation topics as shown in Figure 2.9. On the other hand, when looking at intern teachers' PCK development in Figure 2.10, there was dashed line circle around the components, which meant that each component had limited interactions together while developing their topic-specific PCK. The researchers stated that intern teachers' pedagogical knowledge did not enhance topic specific PCK development as well as expert teacher pedagogical knowledge. In other words, SMK primarily increased the development of their PCK.

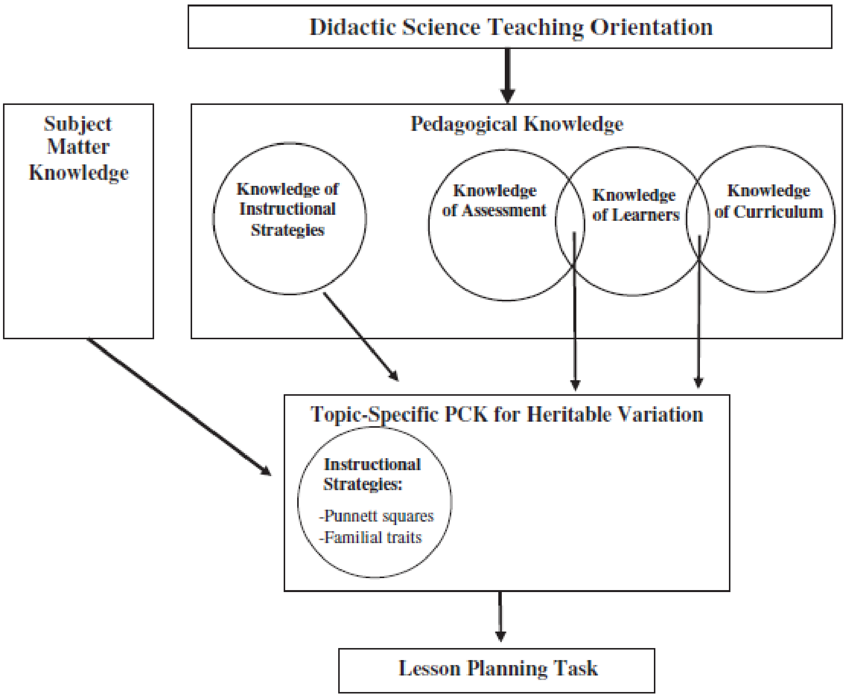


Figure 2.9. The Interactions of Expert Teachers' Knowledge Bases

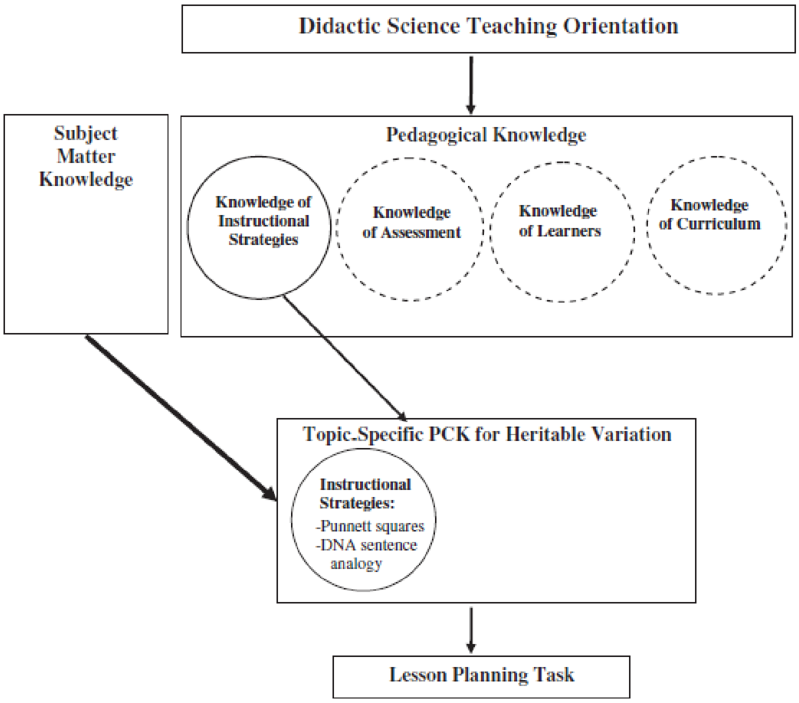


Figure 2.10. The Interactions of Intern Teachers' Knowledge Bases

Up to the present study, researchers focused on investigation of the relationships among teachers' knowledge bases such as SMK, PK, contextual knowledge or PCK, and their aims were to enhance or determine teachers' professional developments. In doing so, they were able to discover some evidence to understand the relationships among knowledge bases. However, next works only focused on determination of the interaction of teachers' PCK components.

Padilla and van Driel (2011) conducted a study with university professors in order to investigate the relationships of their PCK in teaching quantum chemistry. They also aimed to analyze the connection among PCK components. A total of 6 university professors were involved in the study and the data were collected by interview questions. The researchers coded each interview data set based on Magnusson et al.'s (1999) PCK model and they created teaching fragments. After determining sub-components and components in each fragment, the relative frequencies of each components and sub-components were calculated to obtain quantitative data. These data were analyzed by using The Princals Methodogy so as to clarify the relationships among PCK components. According to the results of the study, each professor drew different PCK pictures but some teaching patterns were parallel. For example, the university teachers had traditional teaching pattern, namely, they reflected didactic or academic rigor teaching orientation. Because they believed that quantum chemistry topic was difficult and complicated for understanding of students, it was an effective way to use teacher centered STO. When looking at interactions among PCK components, four professors connected KoC and KoL, three professors had similar interaction between STO and KoIS, or KoL. General teachers' profile indicated that all PCK components linked together at a certain rate, but KoA generally was interacted at least component with others. In this respect, the university professors did not pay attention to use KoA. In this study researchers focused to clarify the relationships between PCK components generally ignored in the science teacher education (Friedrichsen et al., 2011). Comparing this study results with Kaya's (2009) work, there were some different features about studies' samples, methods, data analyzing techniques. However, the findings occurred with parallel. There were significant correlations among participants' KoC, KoL, and KoIS in both studies. Moreover, KoA had low correlations with other components. However, any information about STO was not considered by Kaya (2009).

In addition to above studies, Park and Chen (2012) extended determination of the relationships among PCK components while they were developing a tool more concrete and measurable than previous studies in PCK literature. The aim of their study was to determine how one component links to others while organizing, developing, and validating teachers' PCK. The qualitative method was used to select four biology teachers in teaching photosynthesis and heredity topics, to collect the data through class observations, interviews, lesson plans, and teachers and students' works, to analyze the data through in-depth PCK analysis, enumerative approach, and the constant comparative methods. Moreover, the researchers employed pentagon model as a conceptual and analytical framework, which includes five components in a mutually interactive way with one component to another (Park & Oliver, 2008). By the way, Enumerative approach is an analysis technique in qualitative designs (LeCompte & Preissle, 1993, as cited in Park & Chen, 2012) to clarify the interaction PCK components more explicitly in an analytic device which was called by the researchers as PCK map. In order to construct PCK map, the pentagon model was used as illustrated in Figure 2.11. This model includes five PCK components and each component can interact with others. In this model, each connection or interaction among two components has similar strength of 1. The researchers first analyzed the participant teachers PCK in depth, and then categorized their teaching in the episodes. For example, six episodes on the right side in Figure 2.11 referred one teacher teaching on photosynthesis topic. Moreover, PCK map showed clearly each episode including the interactions of PCK components.

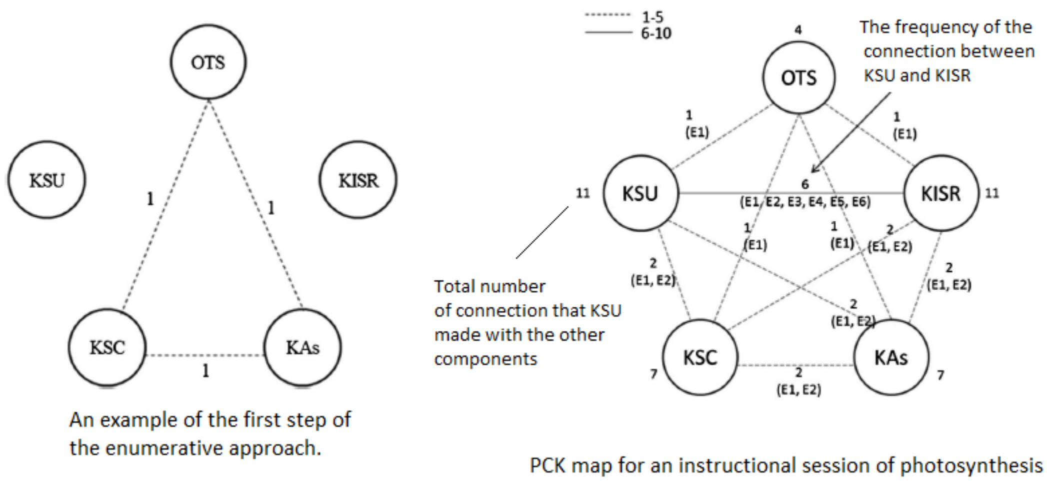


Figure 2.11. The construction of PCK map by using enumerative approach (Park & Chen, 2012, p. 929-930)

As regarding the study results, five distinctive results were appeared. First one was related to topic-specific PCK. Each participant teacher reflected the interactions of components in idiosyncratic way. Although each teacher had used similar approach during planning process and similar contents, they presented different PCK maps. The second distinctive result was that KoL and KoIS played important role during planning and practicing process, and they were more interacted than other components. The third one was that KoC was engaged in at least interactions, and the teachers used KoC with the most interaction of KoIS. The forth specific result was related to KoA. Contrary to previous studies (Kaya, 2009; Padilla & van Driel, 2011) focusing on the relationships among PCK components, Park and Chen (2012) was able to determine the effect of KoA on other components. KoA was more interacted with KoL and KoIS than STO and KoC because the participants used informal assessment skills such as questioning or monitoring student performance so as to determine students' outcomes. In this respect, KoL and KoIS were more employed in interaction with KoA. The last result was related to shaping STO to others. STO affected KoIS and hindered its interactions with other components. To sum up, Park and Chen (2012) investigated teachers' PCK by using different approach "mapping out the integration of PCK components" and they obtained evidence which were compatible with literature in terms of topic-specific PCK. They also emphasized that KoL and KoIS were crucial components on the teachers' professional development.

After developing mapping out approach by Park and Chen (2012), many researchers used it to organize and conduct their studies, and to validate mapping out approach with empirical evidence. One study was conducted by Aydın and Boz (2013) to examine the nature of interaction PCK components while two expert teachers were teaching the redox reactions and electrochemical cells topics. The participant teachers worked in a private high school and had 15 and eight years teaching experience. The study included qualitative nature and semi-structured interviews, card-sorting activities, CoRe, observations, and field notes were used to collect the data. Data analyses process included in-depth PCK analysis, enumerative approaches (based on Park and Chen's (2012) approach), and constant comparative methods. The interaction PCK components arose from the data of observations and field notes and they developed a rubric to determine the strength of the interactions. After coding the interactions by using the rubric, they generated PCK maps for each teacher and topic. According to the results of the study, different interactions, scores arising from rubric, and PCK maps were detected from participants' teachings. One teacher reflected 22 interaction episodes and 32 points in redox topics and 30 interaction episodes, and 45 points in electrochemical cells topic while another teacher presented 19 episodes and 33 points, and 27 episodes and 39 points, in respectively. Only one teacher took full credit (3 points) from the interaction between KoL and KoIS in electrochemical cell topic while another teacher got three points from two interaction episodes (KoC-KoIS and KoL-KoIS). KoIS and KoL were more interacted components with others but KoA was least integrated PCK component. When closer looking at PCK maps, each participant map was topic-specific and idiosyncratic. Moreover, the interaction episodes included from simple (one components informed another one) interactions to complicate (two or more components informed another component). Similar to previous studies, STO shaped the teachers' teachings. The frequencies of interaction components were different in terms of both topics and teachers. Finally, the integration among PCK components in teaching a topic was complicated process and included four parts; understand, decision-making, enactment, and reflection. In the understanding part, KoL and KoC were active components in order to understand students' prior knowledge or alternative conceptions. Second part of decision making process, STO shaped the teachers' teaching and KoIS was selected by teachers under their belief of STO. Then, the teachers presented related topics in the third step enactment. The last part of interaction process was reflection. The teachers reached a decision-making process in which instructional strategies and assessment techniques were more appropriate for students understanding.

Another study including mapping out approach was designed by Aydın et al. (2015) but in different context. They conducted the study aiming to investigate nature and development of interaction PCK components of preservice teachers. They selected three preservice teachers; two of them were females and one of them was male who were a final year students. The study context involved practicum course lasting 14 weeks and they designed this course enhanced by content presentation (CoRe) based mentoring system. Moreover, the pre-service teachers were assigned to prepare CoRe lesson plans and they participated in educative mentoring helping them in finding solution of their problems facing from designing CoRe lesson plans. Magnusson et al.'s (1999) PCK model was used as both conceptual and analytic framework. The data were collected by pre-post core plans and interviews in order to define the interaction of PCK components. They employed three data analyzing process, namely, deductive method, content analysis, and constant comparative methods. After analyses, pre-post interactions of the teacher maps were formed. The results of this study showed that pre-service teachers developed their PCK until at the end of the course. At the beginning of the course, they had lack of interaction components and the number of interactions was less. However, the teachers presented the interaction of all components in the post PCK maps. The researchers indicated that if it was offered to pre-service teachers to participate in opportunities like CoRe mentoring system, they can enhance their PCK. Moreover, development of the pre-service teachers' PCK was idiosyncratic. CoRe based mentoring system more increased the interaction KoC components. Finally, KoA also did not link with KoIS in any map but KoA interacted the others (STO, KoL, KoC).

The studies including the interaction of PCK components have increased their popularity in scholars working on science teacher education. Recently, Ekiz Kıran (2016) conducted study to investigate experienced chemistry teachers PCK. She focused on each component of PCK and portrayed the interaction of STO with other components. She selected two experience chemistry teachers working in a public school and mixture topic including homogeneous, heterogeneous and separation of mixtures sub-topics. She used qualitative research design similar to PCK literature, and interviews, class observations, and field notes/classroom documents were employed to obtain the data. Different from Magnusson et al.'s (1999) PCK model, she focused on the nature of science while investigating teachers STO (Friedrichsen et al., 2011). In this respect, she added Views of the Nature of Science Questionnaire Form-C (VNOS-C) (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) to data collection tools. The data analysis process included Magnusson et al.'s (1999) PCK model to code teachers' PCK and components deductively, and Aydın and Boz, (2013), Park and Chen, (2012), and Padilla and Van Driel (2011) coding schemes to analyze the interactions of STO with other components. According to the study results, the participant teachers did not present any aspect of NOS through practicing part of their teaching. They stated that some limitations such as lack of time, teachers' belief towards NOS, and nationwide examinations led to hinder the employment of NOS. STO interplayed with other components of PCK but the variation of interaction differed by the teacher. Moreover, the teachers had different beliefs about goals and purposes, and science teaching and learning but they focused on some similar beliefs on their teaching practices such as everyday coping, solid foundation and correct explanation. Nationwide examination played important role on the development the teachers' goals and purposes, thus, they reflected teacher-centered teaching orientation in their presentations and activities. When KoL component was examined, the teachers believed that neither students' difficulties/misconceptions nor students prior knowledge affected their teaching in a negative way because the students had correct and enough knowledge to understand mixture units. In other words, they did not have enough ability and knowledge to analyze students' understanding of science. Different to KoL, KoC was strongly developed by the teachers, which arising from teaching experience and other factors such as writing books. Because of their STO, they generally reflected didactic teaching methods. Moreover, the teachers did not present any subject-specific instructional strategies during their teaching of mixture topic. Summative assessment was important for students and helped preparation of nationwide examinations. When analyzing the interaction components results, the researcher coded teaching behaviors as the interactions of the components which appeared both the teacher planning and practicing process. The researcher separated STO into three sub components; beliefs about goals or purposes, beliefs about teaching and learning, and beliefs about NOS. The first sub-component interacted with same components, in which teachers aimed to provide correct explanations in order to construct solid foundation of learning. In this respect, teachers used teacher-centered instructional strategies or activities in order to reach their goals and purposes, namely, KoIS interacted with the first sub-component. In other words, the teachers' wanted to provide students with solid conceptual understanding in order to make the students getting full credit from their examination. On the other hand, KoL and KoA more interacted with the first components than KoC. Generally, these interactions also had similar feature for two teachers. When looking at the interactions between second sub-component and others, KoIS played important role and it interacted all sub-components. However, KoA interplayed at least with that component. The researcher explained this situation as resulting of the teachers' STO, namely, teacher-centered teaching and learning hindered the interaction of KoA with others.

Similar to Ekiz Kıran's (2016) work, Demirdöğen (2016) conducted pre-service teachers' PCK study in order to determine the relationships between STO and other components such as KoL, KoIS, KoC, and KoA. She used Magnusson et al.'s (1999) PCK model as a conceptual framework, and Friedrichsen et al.'s (2011) definition of STO was utilized to enrich her data bases. Case study design in qualitative-interpretive nature was employed to portray the interactions of PCK components. Demirdöğen selected eight middle school science pre-service teachers in the last semesters in their program. She collected the data by using open-ended questions, CoRe, questionnaire about NOS, and semi-structured interviews. In this respect, in order to determine teachers' PCK components interactions, CoRe and interviews were utilized as main data collection tools. According to the data results, participant teachers' goals and purposes for science teaching affected all PCK components. Especially, content based purpose interacted with all components. Another purposes such as the development students' science process skills, and everyday coping interplayed with KoC, KoIS, and KoA. Moreover, the sub-component of teachers' beliefs about NOS was not directly used by the participants. Although the participants had enough knowledge about NOS, they did not have enough ability to present it in the teaching context. The final result of this study was related to other sub-component of STO. Teachers beliefs on science teaching and learning were mostly connected with KoIS, except for some cases such as it interacted with KoC or KoA. To sum up, Demirdöğen (2016) stated that pre-service teachers' PCK were idiosyncratic in nature. There were both similar features of STO and different features or interactions. Also she detected some interactions among KoL, KoC, KoIS, and KoA as seen in PCK literature.

Most recently, Akın (2017) completed her dissertation in which the interaction of PCK components were examined in reaction rate and chemical equilibrium topics. The researcher focused on clarifying the nature of interaction PCK components between novice and experienced teachers, and to determine the effect of teaching experienced on the interactions. She designed her study based on

Magnusson et al.'s (1999) PCK model (similar to PCK studies in the literature) and Park and Oliver's (2008) pentagonal model (new methodology to construct PCK map, see Figure 2.11) as conceptual and analytic framework. Regarding the frameworks, qualitative-interpretive nature provided valuable data arising from multiple cases studies including two experienced and one novice teachers. Similar to previous studies (e.g., Aydın & Boz, 2013; Aydın et al., 2015; Park & Chen, 2012), Akın's (2017) study included similar research design, and the data were collected through card-sorting activities, pre-post interviews, CoRe, and classroom observations. However, there were some differences from previous studies such as sample of the study including experienced and novice teachers, investigation of all PCK components' interactions, and using pentagonal mapping approach. On the other hand, study topics reaction rate and chemical equilibrium are a part of chemistry, which is selected by researchers commonly. Within this mind, Akın summarized the results of study as follows; (1) similar to previous studies, idiosyncratic and topic-specific nature of PCK appeared in the interactions of components. (2) There was a difference between novice teacher and experienced teachers' PCK maps in terms of fragmented and integrated respectively, and PCK maps showed the different level of complexity. (3) There was also difference about teachers' STO. Novice teacher reflected broad and non-specific orientation but others represented more specific orientation. (4) During teaching related topics, KoL, KoC, and KoIS acted as central components. This result is compatible with the previous studies in which KoL and KoIS played active role but KoC was not considered by the participant teachers. In this respect, Akın' result offered an evidence about the effect of KoC on teachers' teaching. (5) Two-way interactions appeared much more over in experienced teachers' maps than novice teacher's maps, and experienced teachers were able to more translate their knowledge bases into classroom practices than novice teacher. (6) Self-efficacy of teachers had an effect to construct teachers' PCK map. To sum up, Akın (2017) explained the differences between novice teacher and experienced teachers PCK facilitating the interactions of PCK components. She reached some conclusions common in the science teachers' literature, idiosyncratic and topic-specific nature of PCK, the main role of KoL and KoIS, differences between experienced and novice teacher PCK.

To sum up, the interaction of PCK components has been considered by many researchers. In the earlier, scholars emphasized that knowledge bases such as SMK, PK, PCK, or contextual knowledge cannot be analyzed separately, and they should combine and interrelate together in a heuristic structure (Abel, 2007; Cochran et al., 1991; Fernandez-Balboa & Stiehl, 1995; Magnusson et al., 1999). Later on, empirical studies were employed to find out some evidence to support previous ideas such as the knowledge bases of university professors (Fernandez-Balboa & Stiehl, 1995), the development of experience science teachers' PCK components in the topic "solar system and the universe" (Henze et al., 2008), and biology teachers in the topic "heritable variation" (Friedrichesen, et al., 2009). Other studies was only focused on the relationships among PCK components such as university professors in teaching quantum chemistry (Pandilla & van Driel, 2011), biology teachers in the topic "photosynthesis and heredity" (Park & Chen, 2012), chemistry teachers in the topic "redox reactions and electrochemical cells" (Aydın & Boz, 2013), chemistry pre-service teachers in the topic "rate of reaction" (Aydın et al., 2015), chemistry teachers in the topic "mixture" (Ekiz Kıran, 2016), middle school pre-service teachers (Demirdöğen, 2016), and chemistry teachers in the topic "reaction rate and chemical equilibrium" (Akın, 2017). In this respect, chemistry teachers and topics were generally considered in above studies. Moreover, the studies showed that KoL and KoIS were most used by teachers and they played active role during teaching process (Akın, 2017; Aydın & Boz, 2013; Fernandez-Balboa & Stiehl, 1995; Friedrichesen, et al., 2009; Park & Chen, 2012). However, the effect of KoA on teachers' PCK was not found out in some studies (Friedrichesen, et al., 2009; Kaya, 2009), or KoA interacted with other components at least (Aydın & Boz, 2013; Pandilla & van Driel, 2011). Finally, some studies did not focus on STO as a component and investigate its effects on teachers' PCK (Henze, 2008; Kaya, 2009).

2.4 Gifted Students' Education and Their Teachers

In this part, gifted students' education, teachers of gifted students, characteristics of gifted students, and enrichment curriculum topics were summarized.

Regarding of the purposes of gifted students' education, there are three main purposes. The first aim is to provide the gifted students with educational opportunities in which they are able to enhance maximum cognitive development and self-fulfillment (Sękowski & Łubianka, 2015). The second aim is to provide the benefit of society, and to increase the talented people reservoir in which talented individuals help to determine society problems and solve them to bear society to contemporary civilization. In other words, the aim is to produce beneficial and productive individuals such as scientists, artists, engineers or leaders (Renzulli, 1999). The last aim is generated from the combination of the first two aims, and it is suitable with democratic philosophy of education. In this respect, creative and productive abilities of individuals play an important role to reach the first two aims; having self-fulfillment gifted students, and providing beneficial to society (Renzulli, 2012). In other words, the last aim is to enhance the gifted students' creative and productive abilities.

In order to achieve the aims mentioned above, in teacher education increasing attention has been devoted to the determination and meeting the special needs of gifted students. In this respect, the first thing to do to understand and identify the gifted students' needs well (Croft, 2003) because they have some particular characteristics observed in classroom context. In the science classes, gifted students interrogate and question new information (Stott & Hobden, 2016), ask challenging, unusual, and insightful questions (Miller, 2009; Park & Oliver, 2009), learn science concepts easier and more quickly than peers (Joffe, 2001; Manning, 2006; Miller, 2009; Park & Oliver, 2009; Taber, 2007), have perfectionist traits to complete any works (Joffe, 2001; Park & Oliver, 2009), dislike routine, notetaking, and homework (Joffe, 2001; Park & Oliver, 2009; Samardzija & Peterson, 2015), enjoy participating complex, discovery, students-centered, self-discovery learning environment

(Friddyment, 2014; Joffe, 2001; Miller, 2009; Samardzija & Peterson, 2015; Taber, 2007), and transfer effectively obtained knowledge and implement it to new conditions (Manning, 2006; Miller, 2009; Stott & Hobden, 2016).

These above characteristics are generally appeared in science classes, and if teachers do not present appropriate instructional strategies, materials, and activities in the right place and right time, these characteristics turn into educational needs for gifted students. For examples, the gifted students tended to complete all works in perfectionist traits. However, it causes to stress, anxiety, or self-criticism, which influence the gifted students in negative way and lead to create unsuccessful works (Park & Oliver, 2009). Moreover, the students suffer from their stress, perfectionism, and flexibility derived from failure of any work or social pressure especially arising from their parents (Joffe, 2001). Another example is that the gifted students could learn science concepts easier and more quickly than their peers in heterogeneous groups. So, it causes the gifted students to be impatient and to get easily bored (Park & Oliver, 2009). Therefore, it is important to note that these negative feeling or results lead to gifted students to become unsuccessful in the regular classroom context, and many educational needs appear for gifted students' teachers to meet them through appropriate and specific precautions.

In this respect, teacher education is more important and the main topic on the agenda. Many researchers agree that teachers of gifted students require engaging in special training programs, endorsements (Kaplan, 2012; Miller, 2009; Shaughnessy & Sak, 2015) rather than formal training which is not sufficient for gifted students' needs (Bangel et al., 2010; Miller, 2009; Mills, 2003). General teacher education programs are not enough to deal with gifted student's needs. Regarding novice versus expert teachers, it is not important whether a teacher expert or novice to meet the educational need of gifted students. If teachers don't engage in a specific professional development process, they don't reflect a sophisticated attitude toward gifted students, and they don't provide effective implementations (Bangel et al., 2010). Therefore, scholars have been in a challenge to organize and implement teaching strategies and behavior management strategies so as to handle the needs of gifted learners. However, majority of the teachers do not have enough knowledge about highly ability groups (Manning, 2006). For examples, teachers do not have an ability to connect among characteristics of gifted students and their competencies. The teachers do not reflect enough pedagogy including logical reasoning, creative thinking, or productivity, and 21st century skills (Kaplan, 2012).

As regarding teachers' professional development, Shaughnessy and Sak (2015) explained the teachers' professional development as following steps. Firstly, teachers need to know the curriculum models for gifted education. However, they don't have enough knowledge to use effectively those models, and only few model or technique is used such as creative development or problem solving. Secondly, teachers should know how those curricula are adapted to regular curriculum applied in their school context because in the gifted education literature, there is no the best curriculum for all gifted students. Thirdly, teachers require developing their specific pedagogies including important skills and applications or activities. And then, it is important to design a lesson or activities by using these pedagogies.

As regarding the curriculum in Shaughnessy and Sak's (2015) perspective, it is not possible to separate curriculum for gifted from regular curriculum because the students need to know general subject topics, objectives, concepts or materials. It is a misconception to teach only skills for gifted students. The most of education programs focus on skill development activities such as mind-bending activities, puzzles or mind games. Those skill activities are not interrelated with mainstream curriculum. Especially in Turkey, it is ignored to develop thinking skills, and how to use knowledge and experience through thinking skills. Moreover, knowledge is very important to develop thinking skills (Shaughnessy & Sak, 2015). To sum up, the curriculum of gifted students' education should include advance knowledge and opportunities in which the gifted students are able to develop thinking skills.

2.4.1 Enrichment Activities or Curriculum for Gifted Students' Education

Although experienced teachers have necessary knowledge and abilities, these characteristics unfortunately are not enough to meet the needs of gifted students (Croft, 2003). Effective and skillfully teachers have ability to determine students' needs, and handle those by using particular strategies or precautions (Pfeiffer & Shaughnessy, 2015). In order to take the precautions in classroom environment, there are some alternative applications such as grouping, acceleration, and enrichment. First one is *grouping technique* in which advanced level talented students are gathered in a small group, and they are asked to work together in effective way. This technique provides students with obtaining knowledge and ability arising from their peers. Some examples are self-contained gifted classroom, pull-out, clustered grouping, and within class flexible grouping. Each of examples requires having proficiency. The second one is *acceleration* in which the gifted students are advanced to upper class or topics. Each class level or topic requires to be completed some specific tasks such as using materials, completing task or assignments, or obtaining skills and knowledge. Gifted students are able to achieve these tasks easier and faster than non-gifted students (Joffe, 2001; Manning, 2006; Miller, 2009; Park & Oliver, 2009; Taber, 2007). Therefore, acceleration is more effective technique for such students. The third one is *enrichment* in which the gifted students are engaged in more horizontal learning environment. Specific content or process is modified into different level including more advanced and extend knowledge and abilities than regular curriculum. Enrichment also provides students abilities such as analyzing, synthesizing, reasoning, and critical thinking (Croft, 2003).

Educational opportunities for gifted education in Europe were summarized by Sękowski and Łubianka (2015) such as precautions in the mainstream school setting, and out of school based activities. Some of them are follows;

1. More advanced and varied activities; it is generally used in secondary school level, and using varied instructional strategies provides the students to obtain subject matters with more depth and extended activities. Individual or group works are the most frequently used activities assigned as homework or class implementations based on students' interest. The individual interest and abilities play important role while designing activities such as preparing a presentation about a specific topic, helping the teacher as an assistant, or participating long-running project. The activities generally include problem based learning providing students to focus on individual-independent working and to encourage them to obtain

information by using that technique. The students also get some abilities in which they organize the knowledge and compare and evaluate the new information with previous that. Therefore, students can creatively solve problems and develop their curiosity.

2. Differentiated provision; it is a special educational support based on students learning race. In addition to mainstream curriculum, particular activities are specially designed to engage students in investigation process. In elementary level, gifted students are educated in separated groups based on their abilities, and the students in secondary level are attended to special school. This technique is frequently used through in the European countries as enrichment curricula of mathematic, informatics, or science and natural science in the direction of individual skills of students. The teachers of gifted students are responsible for designing and implementing related activities or applications for their students. These teachers are called mentor teachers or experts. The teachers should also have competencies designing enrich and challenging curricula so as the student to discover their special powers and abilities. As a conclusion, though European countries, gifted education have not been set in systematic education yet.

In Turkey, there are limited educational opportunities for gifted. It is the most common applications science and art centers including different application, content or activities that are changed from one center to another. The center curriculum is changed based on teachers' beliefs and experiences. Ministry of National Education (MNE) supports to design and apply enrichment programs but it does not tend to consider accelerations. Grade skipping is applied only the first grade or fifth grade level, and one student can only skip the class one time. Moreover, MNE has a view that education of gifted students in homogeneous groups lead to create elitism and negative effect on gifted students' development (Shaughnessy & Sak, 2015).

Although enrichment activities including inquiry, discovery learning, problem solving, and creativity provide both gifted and non-gifted students to meet the needs, acceleration, grouping, and highly enriched curriculum are more appropriate for gifted students than other curricular methods (Croft, 2003). The teachers are able to answer how much their students need to take enrichment activities, what degree of speed is more appropriate for the students, how much challenges and frustration can be tolerated by the students in enrichment activities (Pfeiffer & Shaughnessy, 2015). In order to design a curriculum differentiation, there are five factors which teachers should have: (1) SMK or content includes concepts, topics, reality, and ideas. They are main aims of educational system. Therefore, teachers have to become expert in a specific content. (2) Process includes teaching methods, activities, or questions, namely it is related to pedagogical knowledge. Process also comprises of acting related content, interacting of students, reacting based on students' feedback, revising curriculum in order to meet the gifted students' cognitive needs. (3) Curriculum models are a powerful guidance for teachers to modify regular curriculum in a systematic way. Some examples are follows; Renzulli's enrichment triad model, Van Tassel-Baska's integrated curriculum model, or Sternberg's Triarchic model. (4) Product includes students' outcomes arising from instructions. It indicates the students' understanding related topics. (5) Environment involves both physical environment and affective factors (Croft, 2003).

Understanding or recognizing of gifted students in science class might not be easy because they should face challenges providing them to use special abilities. If gifted students are supported with right time and right educational activities, they can present exceptional performance (Taber, 2007). It is agreed that gifted students have special needs and regular science curricula are deficient to meet these needs. "Zone of proximal development" (ZPD) and "zone of actual development" (ZAD) (Vygotsky, 1978) explain the differences between regular science curriculum and needs of gifted students. ZAD provides non-gifted students to obtain targeted concepts and abilities because evaluation criteria in regular curriculum should be at a level lower than what an individual can learn on his own. In this zone, neither gifted students can realize their special abilities nor do they enhance their abilities. However, true and real developments of abilities appear in ZPD helping gifted students reach new competencies. Within this mind, effective science teachers should design enrich educational environment in which gifted students transfer their learning from ZAD to ZPD. However, in school settings, students take place actively in ZAD with regular knowledge and applications, and they rarely present learnings in

ZDF (Taber, 2007). Therefore, they have not enhanced targeted knowledge and abilities. The gifted students engaging in activities in ZAD are also bored with regular science curriculum (Joffe, 2001; Park & Oliver, 2009).

To sum up, designing enrichment curriculum or activities requires the teachers to have specific competencies, knowledge, and experience. Therefore, many researchers agree that teachers of gifted students require engaging in a special training programs rather than formal training which is not sufficient for gifted students' needs to enhance teachers' professional developments (Bangel et al., 2010). With this in mind, the effectiveness of enrichment programs was investigated in the rest of this part as follows.

In order to increase the experience of pre-service teachers with gifted students, Bangel et al. (2010) designed two special training programs for pre-service teachers such as Saturday enrichment program and online course introducing concepts of gifted education. The aim of the study was to enhance pre-service teachers' understanding of the needs of giftedness. The study included undergraduate students who participating in gifted education course and enrolling to teach Saturday enrichment program in elementary education program. The study had qualitative nature, and the data were collected with interviews, classroom observations, lesson plans, and practicum survey. The Saturday enrichment program was a practicum experience for pre-service teachers gaining to specific experience about accelerated and enrichment activities in mathematics, science, technology, engineering, humanities, and arts. On the other hand, the online course was designed to teach characteristics and the needs of gifted students over 16-week. As regarding the results of the study, pre-service teachers believed that there was an increasing their knowledge about characteristics and special needs of gifted students. In this respect, online course and practicum with gifted students provided pre-service teachers with valuable experiences. Moreover, pre-service teachers recognized a development on their confidence level during practicum and training process in terms of general teaching abilities and how apply these abilities into practices. The Saturday enrichment program was more beneficial to obtain teaching experience with gifted students than regular field experiences. And finally, pre-service teachers believed that the two enrichment program provided them with an authentic learning experience. After finished the two enrichment programs, pre-service teachers believed that they gained valuable knowledge and abilities such as classroom management, curriculum development, parental relations, and other general skills. These knowledge and abilities are related to general pedagogical knowledge of a teacher. However, a real teaching appears in real teaching practices in which pre-service teachers have to use their PCK and components. In this respect, we can analyze the pre-service teachers' effectiveness to teach any concept of topics to gifted students. However, this study did not involve the teachers PCK. In this study, authors stated that special teacher training programs should be designed for pre-service teachers to enhance their general pedagogy and professional knowledge. In here a question arises from this study. Is the enrichment program enough for pre-service teachers to meet the needs of gifted students without focusing of teachers' PCK?

In the school settings, enrichment activities are designed to provide the gifted students with effective school programs. Therefore, Aljughaiman and Ayoub (2012) investigated the effect of enrichment program on elementary gifted students. They designed an enrichment program based on successful intelligence theory which refers that gifted and talented behaviors derive from in a combination of analytical, creative, and practical abilities. Thus, the researchers aimed to increase the students' analytical, creative, and practical abilities by using an enrichment program. Analytical abilities are considered as a component of intelligence processing helping to gain information through analyzing, evaluating, comparing and contrasting or making judgments related phenomena. Moreover, creative abilities involve that one reflects insight, intuition, or forming new products or novel explanations. The last components of practical abilities are a combination of creative and analytical abilities that practice effectively into daily life situations. In this respect, the study defined gifted students that ones are able to balance on combination of these above abilities and application of them into daily practical situations. This study had a quasi-experimental design including pre-post measurements with experimental (20 gifted students) and control groups (22 gifted students). The participant students were 5th

and 6th grade elementary gifted students who were selected by using the ability test having criteria of the top 5%, and students' general achievement tests scores on the top of 90%. The experimental treatment included three enrichment units and each unit had three sub-units in order to enhance students' analytical, creative, and practical abilities over the six weeks. The results of the study explained that there were no significant differences among pre-test scores of two groups but significant differences among groups appeared in terms of analytic and creative abilities. On the other hand, there was no significant difference between experimental and control groups in terms of practical abilities. As a result, the enrichment program aiming to enhance the gifted students' analytic, creative, and practical abilities was only beneficial to increase students' abilities in terms of analytical and creative. On the other hand, practical abilities of participants were not enhanced by the enrichment program. The authors suggested that special attention and more robust activities should be used in enrichments program to enhance students' practical abilities. Finally, the enrichment program was not successful to develop three abilities in an equal and sufficient way. The study results can be interpreted based on Vygotsky's (1978) view of "Zone of proximal development", and Renzulli's (1999) definition of giftedness. The enrichment programs in this study were not able to reach the students to enhance their practical abilities requiring some challenging and advance work for the gifted students similar to activities in zone of proximal development. True and real developments of abilities appear in ZPD helping gifted students reach new competencies (Taber, 2007). On the other hand, Renzulli (1999) defined two types of giftedness: (1) "lesson-learning" or "schoolhouse" giftedness and (2) "creative productive" giftedness. The first group of students presents high level of achievement on cognitive skills, and there is significant correlation between these giftedness and school achievement. Moreover, regular curriculum materials are enough for these students to show their performance. However, the type of students is creatively productive giftedness that has specific abilities to design or development of original ideas, knowledge and abilities, products, or artistic expressions. These group of students need to obtain learning situations including creative and practical skills. The enrichment programs in this study could be designed in a complexity level based on lesson-learning" or "schoolhouse" giftedness, thus, the participant students did not reach the behaviors on the level of practical abilities.

The large number of scholars agreed that gifted students need to further supports in addition to regular science curriculum (Renzulli, 2012; Winstanley, 2007). Enrichment curriculum is an effective approach to meet the needs of those students. An example of additional support was designed by Çalıkoğlu and Kahveci (2015) to investigate the effectiveness of enrichment curriculum including depth and complexity in the science curriculum. The aim of the study was to determine their differentiated science curriculum effect on 5th grade gifted students. It was experimental study involving pre-post measurement in two groups such as control and treatment group offered to depth and complexity enriched curriculum. The authors used three set of scales such as academic achievement test based on the topic of "Exploring and Getting to Know the World of Living Things", scientific process skills test, and scale of attitudes toward science education to gather data. The treatment "depth and complex science curriculum" were applied over four weeks including two 40-minutes class time. Regarding result of first academic achievement test, there was a significant difference between pre-test and post-test in treatment group, namely, the students score increased after treatment. However, in control group, there was no significant difference. Moreover, achievement post-test scores of treatment group differed significantly from control group' scores. Regarding to students' science process skills, similar results appeared with achievement scores. In other words, post-test results of science process skills significantly differ from pre-test score in treatment group, and not significant result was found between pre-test and post-test in control group. There was also difference between treatment and control groups test scores in favor of treatment group. Regarding of the attitude toward science education, comparing pre-test with post-tests, similar results with previous scale scores were found, namely, there was significantly difference between pre-test and post-test results in both treatment group and control group's attitude scale, in favor of post-test. However, no significant differences appeared between control and treatment groups. To sum up, enrichment program including depth and complexity science curriculum increased the gifted students' achievement scores, science process skills, and attitude toward science education. Well-designed educational supports or such attribute can help gifted students to enhance knowledge and abilities through engaged them in challenging situation similar to zone of proximal development (Vygotsky, 1978).

Newman and Hubner (2012) conducted a study to determine the influence of Summer enrichment workshop (SEW) designed by using partnerships of team including engineering, gifted and talented faculty members, and two middle school science teachers. Engineering professors helped to increase the challenge of science mini-courses. The aims of the study were to investigate the teachers' perception about their competencies and confidence after SEW, and how challenge of mini-courses was raised by the engineers. Mixed method design was used to employ the study. The participants of the study included two science teachers having 5 and 13 years of experience with gifted students in pull-out program, resources room situations. The data were collected by surveys, lesson plans, observations, interviews, teachers' written reflections, students work samples, and researchers field notes. Results of the study indicated that the partnership team was able to achieve the increase the challenge of science mini-courses. This study also presented evidence that teachers having strong SMK and instructional knowledge are the most effective factor in teaching science. Moreover, university staffs provided two teachers with improving of content challenge during planning stages. Working with faculty professors increased both teachers and students' motivations toward science learning and activities including conducting and investigating researches, and solving problems. Moreover, teachers gained important knowledge and skills by engaging in the partnership team. Professors helped the teachers facilitating as mentor, assistance, giving feedback, reflections to design and implement inquiry based science and problem solving teaching. Thus, this supports enhanced the teachers' SMK and PCK. Also the teachers believed that the mentoring of professors and other facilities enhance the teachers' competencies and confident in designing, implementing, managing students' learning. To sum up, after SEW, the participant teachers gained a valuable experience in terms of improving the challenge level of science content, designing and delivering that content by using appropriate instructional strategies, and encourages to increase competence and confidence to teach science.

Kim (2016) conducted a meta-analysis about the influence of enrichment programs on gifted learners. The aim of the study was to evaluate the studies between 1985 and 2014 years, and including enrichment opportunities for gifted students in terms of socioemotional development and academic achievement. The enrichment curriculum was called that in order to enhance gifted students' skills and conceptual understanding, teachers change, modified or redesign regular curriculum to generate a new curriculum or activity including more enriched and deeper concepts, topics, or materials. The enrichment programs were investigated in following criteria; designing educational supports beyond mainstream class activities, applied over the school year or summer, and designing to support gifted students. In this respect, 26 studies having enough parameters such as effect sizes (13 are related to academic achievement, and 16 are socioemotional studies) were employed in this study. According to the results of study, the enrichment programs or curricula have a positive effect on gifted students' both achievement and socioemotional outcomes. Regarding achievement scores, grade levels (elementary, middle school, and high school) of effect sizes significantly differed from zero and the enrichment programs had the most effect on high school gifted students and at least effect on elementary school students. On the other hand, summer school enrichment programs had the most effect size than other programs such as academic year programs, Saturday programs or combination of summer and academic year. Regarding socioeconomic outcomes, the middle school students' effect sizes were the biggest value, and at least effect appeared among high school gifted students. When looking at program types of enrichment programs, the largest effect size appeared in summer residential programs, and then, academic school years' program had bigger effect size than summer day programs. To sum up, summer school enrichment programs had the most effect on students' both achievement and socioemotional outcomes.

As a conclusion, as we know that gifted students need to get additional educational facilities so as to recognize and to enhance their special abilities.

Therefore, enrichment programs are designed for gifted individuals to meet the special needs. In the literature, enrichment programs generally have positive affect both students' and teachers' perspective (Heath, 1997; Johnsen, et al., 2002) such as achievement and socioemotional outcomes (Kim, 2016), teachers' and students' motivation toward science, teachers' confidence to design and implement for enrichment activities (Newman & Hubner, 2012), students' achievement, science process skills, and attitude toward science (Çalıkoğlu & Kahveci, 2015), students' analytical and critical abilities (Aljughaiman & Ayoub, 2012), and teachers' knowledge and perceptions of gifted students (Bangel et al., 2010).

2.4.2 Teacher Knowledge of Characteristics of Gifted Students

In order to enhance the teachers' professional development for gifted students, educational supports have been designed and implemented nowadays such as certification programs, undergraduate courses, summer schools, etc. The content of these programs should include teachers' academic and pedagogical competencies, and knowledge of the nature of the giftedness (Kaplan, 2012). In this respect, knowledge of the nature of giftedness plays the important role while designing and implementing of enrichment programs. Therefore, effective and skillfully teachers have ability to determine students' needs, and handle those by using particular strategies or precautions. The teachers are able to answer how much their students' need to take enrichment activities, what degree of speed is more appropriate for the students, and how much challenge and frustration can be tolerated by the students in enrichment activities (Pfeiffer & Shaughnessy, 2015). In this respect, the part of this study explained the studies related to teachers' knowledge of characteristics of gifted students.

The first study was conducted by Samardzija and Peterson (2015) to determine the gifted students' learning and classroom preferences. With this study, they aimed to understand students' preference for learning and what classroom characteristics students concern during their learning. The study method was a qualitative nature with 23 eight grade gifted students who were engaging a special curriculum in the middle school. The data were collected only by individual interviews. As regarding the data results, the participant students identified three factors teachers should have such as teachers' competence, concern, and personality. Regarding of teachers' competencies, the authors separated two sections of teachers' competencies such as in control related to classroom management and professional credibility related to ethical working, teachers' appearance. Regarding of teacher personality, many of the students agreed that teachers should reflect helpful, enthusiastic, calm and good-humored behaviors. On the other hand, the students expressed their views about learning environment as engaging in complex learning process. Most of the students tended to engage in activity oriented learning. These activities also should include variety enriching by different techniques or topics. They did not like taking notes and doing same things in every day. According to the students' learning style, they rated learning styles as visual, kinesthetic, and auditory but the rate of auditory was low. Hands-on activities or lab works for kinesthetic provided the students to gain permanent learning. Moreover, group works and independent studies were preferred by the students. In English classes, the gifted students tended to join more discussion than paper-pen activities.

In this regard, researchers focused on some educational needs of gifted students while designing any enrichment programs such as type of activities, learning styles, teachers' personalities, or students' concern. These factors are very important in addition to teachers' SMK in order to provide effective learning environment. The next study is supported to previous one. According to evidence based research conducted by Mills (2003), educational supports such as formal training or certification programs might not be enough to develop teachers' professional competencies for gifted students due to the fact that those educational attempts generally include SMK on a specific domain. However, some personal or cognitive characteristics should be considered while designing training programs. Teachers should develop their cognitive styles in different way or have varied kinds of teaching styles in order to handle situations where gifted students need to use different learning strategies or styles. It is also important that teachers are able to be aware of their students' characteristics, learning styles or etc., and what factors distinguish gifted students from their peers. As a result, although majority of teachers have advanced degree of teaching experience, few teachers have an experience arising from formal training for gifted students (Mills, 2003).

Another study was conducted by Stott and Hobden (2016) to understand the nature of gifted students in terms of their learning strategies. The participant student, who was 14 years old, engaged in enrichment and acceleration program. The study method was a case study in qualitative nature. The data were collected by field notes, journal entries, interviews, and critical incidents. According to the results of the study, participant student did not accept teacher explanations easily and he was in a position interrogating and questioning new information. This strategy was called as *"Interrogating Information".* Second one was *"Thinking It Through"* in which the student tried to change the features of a situation in order to understand more deeply. In other words, he modified the knowledge and compared it with his preexisting knowledge. The last strategy was "*Linking and Organizing*" in which he connected new information to preexisting knowledge. He could analyze the relationships among knowledge in the activities first, then he could change or make the connections strong among it. Finally, he could transfer and apply it to new situations. In this study, the authors determined a gifted student's learning strategies during the long term observation, and they offered valuable information for someone who aims to design and implement enrichment program or activities.

The projects or training programs are very beneficial with regard both students and teachers (Aljughaiman & Ayoub, 2012; Bangel et al., 2010; Çalıkoğlu & Kahveci, 2015; Newman & Hubner, 2012; Kim, 2016). After developing a training program, Johnsen et al. (2002) reported that the teachers' abilities increased and there were significant changes appeared by the teachers in their classroom practices from little adaptation to more adaptation for gifted students. Following factors affected the classroom changes such as; teachers' positive attitude toward training program, well-design project, freedom to choose goals and purposes, mentoring, and leaderships supports, effect of students.

Designing a teacher professional development was appeared in Fiddyment's (2014) study to investigate teachers' attitude toward enrichment clusters. Two gifted teachers participated in enrichment clusters group setting. After training, both teachers had positive attitude toward enrichment clusters. The needs to design for enrichment clusters are time and money, teachers' professional competencies (theoretical and practical experiences), students-centered classroom setting, students' interest.

The studies reviewed until now investigate teachers' perceptions and knowledge of gifted students, competencies of designing enrichment activities, or characteristics of gifted students. However, these studies do not emphasize the teachers' knowledge bases such as SMK, general pedagogical knowledge or PCK. The closest studies having PCK criteria but not all PCK components are to explain in the next two studies.

The first one was conducted by Park and Oliver (2009), and the aim of this study was to investigate the effect of gifted students on teachers teaching. Gifted students have some special characteristics, which cause particular instructional challenges for teachers. In this regard, the authors aimed to determine what instructional challenges are appeared by the gifted students in the science classes, and how the instructional challenges affect the teachers' KoIS. This study involved a qualitative nature with three chemistry teachers working in homogenous or heterogeneous gifted students' classroom. The data were collected by multiple data tools such as interviews, classroom observations, lesson plans, teachers and students work examples. Findings were grouped in two parts in the study. First part, instructional challenges were determined to analyze the characteristics of gifted students appearing into science classroom. There were many pedagogical difficulties, and the authors stated that the characteristics of gifted students led to those difficulties. For example, asking challenging questions, the gifted student asked to unusual and insightful questions, and some of them were out of teachers' content knowledge but they were not nonsense questions. Another example was related the pace of their learning. The gifted students could learn science concepts easier and more quickly than their peers in heterogeneous groups. So, it caused the gifted students to be impatient and to get easily bored. This characteristic also appeared in homogenous groups because gifted students had different learning approaches.

Moreover, the gifted students tended to complete all works in perfectionist traits. However, it caused to stress, anxiety, or self-criticism, which influenced the gifted students in negative way and led to create unsuccessful works. Another characteristic of gifted students was to dislike routine, notetaking, and homework. They liked to engage in complex works whereas others were considered as busywork. They also reflected a feature in which teachers or peers were criticized by the gifted students when they failed to complete a work. This characteristic created a problem when they engaged in a group work in which the gifted students tended their peer to achieve similar performance as they did. The last characteristic occurred among gifted students as being quiet during class. Their peers were aware of the gifted students' performance arising from cognitive, social, or emotional, so the gifted students were subjected to teasing or verbal abuse. So as to handle those peers' pressures, they did not engage in teaching activities. To sum up, teachers faced the pedagogical difficulties arising from above the characteristics. In this respect, teachers must develop some precautions (instructional strategies developed by teachers are related to second part of findings) in order to handle those difficulties. First one was *instructional differentiation* providing the students to engage in a learning environment their own pace. Especially thematic units were used by teachers when they faced the difficulty driven from students' intellectually performance than peers. The units included learning activities where all the students gain better understanding about related core concepts. Moreover, teachers designed inquiry learning environment in which the students were able to work with real life problems, and to find out the solutions of the problems in involving each student's pace and ability. The second instructional strategy was to use *variety in instructional strategies and alter students' assignments*. In order to overcome the needs of gifted students, teachers arranged their teaching by facilitating demonstrations, discussions, and technological-assistant instruction, simulations, or lab works. Moreover, students' products or assignments were designed their special abilities, such as written, visual, performance, or oral forms. These products also provided students to enhance special abilities. The third instructional strategy was to *create group works and provide peer learning*. Especially, the strategy was used in heterogeneous group in which gifted students could learn to be patient and non-gifted students could enhance their knowledge and abilities by facilitating gifted students' help. The fourth strategy developed by the teachers to meet the gifted students' needs was to provide *individualized supports*. The fifth strategy was to offer *challenging questions*. The sixth one was to *overcome perfectionism*, in which the teachers helped the gifted students were aware of their deficiencies about related concepts or applications, and to be designed accessible aims. The last strategy was to *create a psychologically safe classroom environment* so as to overcome the pedagogical challenge arising from non-gifted students' teasing or verbal abuse. As a result, this study showed that the classroom having gifted students needs to meet some special pedagogical challenges, and the teachers were able to generate their instructional strategies based on the students' characteristics. Thus, science teachers require to know content-specific and students-specific instructional strategies because they have gifted students who gain science concepts varied instructional strategies different from each other.

Another study was conducted by Joffe (2001) to determine characteristics of gifted students, and educational needs. Case study method was used and one classroom teacher working with fifth grade students was selected. The teacher did not have any educational background about gifted students' education or their characteristics. Thus, the second aim of this study was to observe the teachers' pedagogical development process. The teacher also had six months teaching experiences with gifted students, and the teacher followed regular curriculum but science and social classes were used to design enrichment activities or academic strength. The data were collected by using interviews. According to the finding, the author grouped the characteristics of gifted students under three titles such as social, emotional, and academic. In the first category, the students were in a competitive position in classroom environment. The second group was emotional characteristic. The teacher experienced the students' stress, perfectionism, and flexibility derived from failure of any work or social pressure especially arising from their parents. When the students could not deal with the failure, they felt burned out or frustrated. The third group was academic characteristic including students learning pace, students' attitude routine, and students' self-discovery. The students' learning pace was generally a concern for teachers because the students were getting bored when they faced slow pace content. So they had a negative attitude toward it. They were also bored to engage in routine works and they could change related works or activities spontaneously. The students tended to participate in discovery learning activities because they felt that they had a potential different from others, and they were able to discover related things. However, the students' creativity did not appear in all the students. The students also asked so many questions and were able to discuss with the teacher and peers. Thus, this characteristic provided the teacher with designing student-centered learning environment. The teacher specially emphasized that the activities including inquiry skills were more appropriate for those students. As regarding the teacher's decision making process, objectives in curriculum were considered as first goal and purposes and then, to enhance students' creativity. As regarding enrichment activities, the teacher accelerated or enriched science curriculum effectively because the teacher was a classroom teacher and had a flexible curriculum. The teacher started the enrichment to determine the students' prior knowledge and abilities, and students learning styles shaped the activities such as trying out, changing, and modifying instructional strategies. Finally, the teacher "Susan" suggested that gifted students should engage in a learning environment having some characteristics meeting the need of gifted students such as learner centered and independence, complex content, group working, and high communication with their peer and teacher.

Two studies mentioned above provided the most of the information about the effects of gifted students and their characteristics on teachers' pedagogy identified only in terms of teachers KoIS. Finally, following two studies focused on characteristics and competencies of gifted students that were explained in terms of teacher and student perspective respectively.

Chan (2001) conducted a study in order to determine teachers of gifted learners' perception of characteristics and competencies of effective teachers. The participant teachers included 50 teachers having from 1 to 30 teaching experiences in primary and secondary teaching setting. 15 of them had being worked with gifted learners but all the teachers did not take any formal education about gifted students.

The data were collected by a check-list involving 25 characteristics and 14 competencies of teachers. According to the findings of the study, teachers believed that teachers for gifted learners should have specific characteristics such as imaginative, knowledgeable, flexible, innovative, motivated, self-confident, and dealing with learner characteristics, which were most rated characteristics by the teachers. On the other hand, teachers rated at least characteristics that a teacher should have as “being highly intelligent, less critical more approachable, cooperative with other personnel, and having control over one's personal life” (Chan, 2001, p.199). Regarding teacher’s competencies, the teachers attached the most importance to following competencies; effective teaching activities including creativity and problem solving abilities, and designing enriched curriculum and materials. On the other hand, the teachers rated some competencies which were at least importance for gifted learner as participating career education and helping other teachers to enhance their knowledge and abilities for gifted learner. Moreover, the author analyzed the effect of teachers’ gender, school levels, and experiences on the teachers’ opinion about characteristics and competencies for gifted learners. And then, he did not find out any significant differences above variables.

After ten years, Chan (2011) supported to previous study with student perspective of characteristics and competencies of teachers of gifted learners. He applied same check-list including 25 teacher characteristics and 14 teacher competencies to 617 gifted students who engaged in enrichment programs in primary and secondary grade levels from 3 to 10. According to the results, the students rated teacher characteristics in the mean ranging from 3.23 to 4.19, and teachers’ competencies in the mean from 3.38 to 4.20 (check-list was rated in 5 likert scale from 1 (not at all important) to 5 (most important)). In doing so, all competencies and characteristics were considered as relatively important. The students selected less important teachers’ characteristics as teachers’ personal attributes including having highly intelligence, knowledge, highly achiever. On the other hand, the students rated teachers’ competencies as less important such as determining gifted students, participating career education or giving consultative services for other teachers. However, the competencies considered as the most important were related to teaching and learning activities including creativity and problem solving abilities, and designing enrichment curriculum and materials for gifted learners. As a results, when comparing Chen's (2001; 2011) works, the mean of the students' results (3.23 to 4.20) were more concerned about their education than the mean of the teachers (2.84 to 4.52).

To sum up, previous two studies provide valuable information about the characteristics and competencies of teachers working with gifted students. Chen investigated those competencies and characteristics in terms of (2001) teachers' perspective and (2011) students' perspective, and both studies show nearly parallel results in order to enhance gifted students' knowledge and abilities. As regarding pedagogical perspective, Park and Oliver (2009) and Joffe (2001) provide science teachers education with valuable information about teachers' KoIS. More previous studies reviewed in this part are related to determination of characteristics of gifted learners, teachers' competencies, concerns, students' learning and classroom preferences, etc. (Fiddyment, 2014; Johnsen et al., 2002; Mills, 2003; Samardzija & Peterson, 2015). These kinds of studies are very superficial in terms of teachers' PCK, and science teachers of gifted students' literature needs to investigate more evidence based research focusing on teachers' PCK in topic-specific nature (Park & Oliver, 2009). Moreover, there are many unanswered questions about teacher's professional knowledge due to the fact that gifted students require to be handled their needs in classroom context. In order to design a differentiation classroom environment, it requires using deep and extra information, high thinking skills, uncommon subjects, experience, more speed, self-directed learning, which are competencies for effective teachers (Croft, 2003). In this respect, these questions appear how teachers gain those competencies, how they design and implement differentiation educational supports, and how gifted learners affect the teachers PCK. The teachers' of gifted learners' education has not yet replied those questions explicitly.

2.5 Conceptualization of PCK for this Study

This study framed a theoretical construct of PCK model offered by Magnusson et al. (1999) including five components; (1) science teacher orientation, (2) knowledge of curriculum, (3) knowledge of learner, (4) knowledge of instructional strategies, and (5) knowledge of assessment. However, science teacher education literature suggests some different sub-components. For example, the horizontal and vertical relations of knowledge of curriculum were suggested by Grossman (1990) and Aydın (2012) that these sub-components should be added to knowledge of curriculum in topic-specific PCK studies. Another suggestion was offered by Friedrichsen et al. (2011), and they explained science teacher orientation under three sub-components; goals and purposes of science teaching, general views of science teaching and learning, and nature of science. I added the first two sub-components such as goals and purposes of science teaching, and general views of science teaching and learning to the PCK conceptualization whereas another sub-component "nature of science" was not integrated into study. According to my pilot study, I investigated the teacher's belief about nature of science but I did not collect any explicit teaching segment. Moreover, in the literature, some specific studies investigated teachers' STO in terms of nature of science aspect in Turkish context and their participant teachers did not use or present any teaching and activities including nature of science aspects (Boesdorfer & Lorsbach, 2014; Demirdöğen, 2016; Ekiz Kıran, 2016; Schneider & Plasman, 2011). Therefore, I did not include teachers' belief about NOS into my study.

In addition to sub-components of science teacher literature, gifted students' education suggests some teacher's knowledge and competencies such as knowledge enrichment curriculum (Croft, 2003; Joffe, 2001; Park & Oliver, 2009; Pfeiffer & Shaughnessy, 2015; Renzulli, 1999; Taber, 2007) and knowledge of characteristics of gifted students (Johnsen et al., 2002; Kaplan, 2012; Mills, 2003; Park and Oliver, 2009). Teachers of gifted students should identify and know their students' characteristics such as learning approaches, learning pace, level of comprehension, critical thinking levels, etc. and then, the teachers are able to design enrichment activities or programs for gifted students. Each of them requires some knowledge, competencies, and abilities for the teachers. Therefore, I added knowledge of enrichment curriculum into KoC, and knowledge of characteristics of gifted students into KoL. To sum up, after integrated sub-components above mentioned, modified version of Magnusson et al.'s (1999) PCK model (as illustrated in Table 2.2) was used as conceptual and analytic framework of the present study. Moreover, data collection tools were developed, and the data were collected based on that model.

Table 2.2. PCK Components and Sub-Components Integrated in This Study

Components	Magnuson et al.'s (1999) PCK model	New integration of sub-components
STO	•Goal and purposes of Science teaching •General views about science teaching and learning.	
KoC	•Knowledge of goal and objectives • Knowledge of specific program	Knowledge of enrichment curriculum Horizontal and vertical relationships.
KoL	• Pre-requirement knowledge • Learning difficulties • Alternative conceptions.	Knowledge of characteristics of gifted students.
KoIS	• Subject-specific • Topic-specific	
KoA	• How to assess • What to assess	

In the PCK literature, there are some definitions of PCK, and researchers use and interpret the nature of PCK in a variety of meaning (Gess-Newsome, 2015; Park & Oliver, 2008). This variability arises from characteristics of students, subject matter knowledge, contexts, or pedagogical knowledge (Loughran et al., 2006). In this respect, nature of PCK is composed of some factors such as subject specific, topic-specific, teacher-specific, and context specific. Each factor has an effect on teachers' PCK (Magnusson et al., 1999). Moreover, teacher's beliefs systems and teacher's efficacy affect teachers' PCK (Park & Oliver, 2008). With this in mind, it is difficult to consider all these factors to engage in a study, so we have to limit "nature of PCK" in this study. Following definition represents the nature of present study.

PCK is a set of knowledge including teacher's purposes and goals, concepts, rich curriculum materials and abilities how a teacher plan, adapt, and practice/enact his knowledge to a group of gifted students to provide understanding subject matter and enhance special abilities by using appropriate instructional strategies and assessment techniques.

In this definition, Magnusson et al.'s (1999) PCK model and its components are integrated with topic-specific in nature. Also the context of study includes 12 gifted students in a private middle school. On the other hand, teacher's beliefs systems and teacher's efficacy were not considered in the present study.

CHAPTER 3

METHODOLOGY

In this chapter, methodological issues were clarified in detail. Before describing the method of inquiry, the research questions were listed as follows:

1. What is the nature of PCK of gifted students' science teacher in teaching the topics of work/energy, simple machines and friction force?

a. What is the nature of gifted students’ science teacher’s knowledge of orientation to science teaching in teaching the topics of work/energy, simple machines and friction force?

b. What is the nature of gifted students’ science teacher’s knowledge of curriculum in teaching the topics of work/energy, simple machines and friction force?

c. What is the nature of gifted students’ science teacher’s knowledge of learner in teaching the topics of work/energy, simple machines and friction force?

d. What is the nature of gifted students’ science teacher’s knowledge of instructional strategy in teaching the topics of work/energy, simple machines and friction force?

e. What is the nature of gifted students’ science teacher’s knowledge of assessment in teaching the topics of work/energy, simple machines and friction force?

2. How do PCK components interplay in teaching the topics of work/energy, simple machines and friction force?

a. How do PCK components interplay in the lesson planning while teaching the topics of work/energy, simple machines and friction force?

b. How do PCK components interplay in the classroom practices while teaching the topics of work/energy, simple machines and friction force?

The aim of this study was to examine the nature of the topic specific teacher's PCK in planning and classroom practicing while teaching three different topics. Thus, the qualitative research provided more detailed information about the teacher's ideas and practices. The following titles explained the qualitative research process in detail.

3.1 Research Design

In order to find out the answer of what and how questions which are the research questions of this study, qualitative research design is an appropriate way (Frankel & Wallen, 2009; Yin, 2009). Qualitative researchers seek out explanation of socially connected phenomena (Denzin & Lincoln, 2000), and qualitative research stresses attempts to explain scientifically or artistically, to discover inductively or deductively, and to search nature of reality in detail (Graue & Karabon, 2013). Qualitative research is an alternative to look for complex social phenomena in the natural environment (Marshall & Rossman, 1989). Qualitative researcher is an instrument and he/she has an opportunity with first-hand experience of obtaining data from participants (Patton, 2002).

As the nature of teacher's PCK, there are complex teacher's knowledge, abilities, and behaviors in the classroom context. Teachers reflect their abilities or knowledge in various form of interaction (teacher-student and student-student). In order to understand teacher's PCK, methods are required to be used which allow the researcher to gain first-hand experience for investigation of teaching environment. For this purpose, qualitative research has been suggested by many researchers (Abell, 2008; Baxter & Lederman, 1999; Magnusson et al., 1999) and it has been used in the teacher's PCK researches (Aydın & Boz, 2013; Friedrichsen & Dana 2005; Loughran et al., 2004; Nilsson, 2008; Park & Chen, 2012; Park & Oliver, 2008; Park, Oliver, & Hall, 2008).

As the nature of teacher's PCK, each teacher is a case to be examined in the teaching process (Shulman, 1987). Since teacher's PCK is affected by content knowledge, pedagogical knowledge, and context; students and their characteristics, school, laboratory, each factor should be analyzed to obtain detailed information. Therefore, case study methodology is more appropriate approach to examine teacher's PCK. Case study is a methodology that finds the answers to questions as to how we do research using different type of methods; interview, observation, etc. (Graue & Karabon, 2013). Case study helps form a holistic and meaningful explanation of real life situations by obtaining information from individuals or groups (Yin, 2009). Case study also explains the causal relationships among individual behaviors which are more complex for surveys and experimental strategies. Another contribution of case study is to describe an intervention in real life conditions and to explain conditions with examples such as interaction of PCK components (Yin, 2009).

In this study, in accordance with the aim of the study, single-case design was selected and the case was identified as a middle school science teacher working with gifted students and teaching three physics topics including work/energy, simple machines and friction force.

3.2 Participants of the Study

The aim of this study was to examine PCK of a middle school science teacher of gifted students and single case design was used to complete the study. Because the case study is a bounded system, the possibility of shifting focus of study is eliminated. Thus, purposive sampling is a more appropriate technique to determine bounded system of the study (Fraenkel & Wallen, 2009; Merriam, 2009). The rationale for using purposive sampling is to help access information-rich cases in order to obtain detailed analyses from the case (Patton, 2002).

In this study, a middle school science teacher was selected by using purposive sampling as the participant who works in a private school in Ankara. Table 3.1 shows background information about the participant of the study. The first step to start using purposive sampling is to specify selection criteria which reflect the aim of the study and guide the formation of the case for obtaining enriched data (Merriam, 2009). Considering the literature on science teacher's PCK and the aim of the study led the way to determine selection criteria.

Table 3.1. Information about the Participant of the Study

Gender	Female
Bachelor's degree and graduation	Physics /Arts and Science Faculty
Master degree and graduation	Physics/ Solid-State Physics
Certificate of education	Pedagogical formation /three semesters
Teaching experience (in years)	One year with regular middle school students Two years with middle school gifted students

In accordance with the aim of the study, first criterion was teacher experience with gifted students. Due to fact that gifted students were not widely recognized everywhere and were not common type of the students (Bélanger & Gagné, 2006; Gagné, 2004; Gilman, 2008; Marland, 1972), it was difficult to find the participant science teacher having experiences with gifted students. In addition, gifted students learning in homogenous classrooms were rare. There were few science teachers, who are responsible for teaching gifted students in Ankara, but they refused to contribute to the study as a participant or their school managers did not allow the study to be conducted in their schools. There were also some science teachers and schools outside of Ankara but it was difficult for the researcher to conduct this study successfully outside of Ankara because of transportation cost, time, and schedule of the participants. Another difficulty of the conducting the study in the different school outside of Ankara arisen from possible teachers' weekly teaching schedules. Due to the nature of PCK studies, the data obtained from participants and their teaching activities must be simultaneously collected by the researcher considering context and science topic taught. Weekly teaching schedules of teachers would overlap with the other teachers' schedules because one teacher would be observed four class hours in a week. If the schedule of a teacher spread over the all days of the week (ex, one class hour in a day; Monday, Tuesday, Thursday, or Friday), it would be difficult for the researcher to collect data from different teachers in the present study.

In Ankara, there are two centers named science and art center where gifted students are educated to realize and enhance their special abilities. The teachers in the center were not appropriate participants for this study because the context of centers was different from those of compulsory middle school classrooms. The teaching skills of science teachers are affected by the school context (Loughran et al., 2006; Park & Oliver, 2008) so the center context would not be appropriate to support the present study. The first reason why the teachers in this center were inappropriate was that the centers have different goals and purposes from compulsory education in terms of science curriculum, teaching science orientation, assessment, and classroom context. Secondly, the centers' curriculum and materials are prepared based on students' abilities and so each teacher might give different activities and contents to their students. Thirdly, science classes in the centers were heterogeneous in terms of students' age (from 11 to 14). Finally, in the centers, science teachers may not reflect their PCK components as a whole. For example, knowledge of assessment component was not considered by the teachers as much as those in compulsory education. For that reason, some components would not be analyzed to determine PCK components' interaction and conducting the study in the centers was inappropriate situation for the aim of the present study.

Due to shortage of science teacher for gifted students and the limitations listed above the prospective participant became as a unique, inaccessible, and atypical. In such cases, a single case study can be selected to obtain detailed and valuable information from the phenomenon of interest (Creswell, 2007; Merriam, 2009; Yin, 2009). Therefore, this study deployed a single case design including a science teacher who was responsible for teaching three physics topics to gifted students.

The second criterion was teachers' experience in real classroom environment. Science teacher's PCK literature stresses that pre-service teacher does not have as strong PCK as that of experience teachers (Abell, 2008; Schneider & Plasman, 2011;

Shulman 1987) because pre-service teachers don't have enough teaching experience in the real classroom setting. In order to obtain enriched information, it was ensured that the participant teacher should have practiced in real classroom setting to middle school pupils. For this reason, the participant teacher had 3 years of teaching experience at the time of this study (one year with middle school non-gifted students, and two years with middle school gifted students). She was also in induction period for gifted students. Induction years of a teacher refers “the first three years of teaching” (Paese, 1990, p.159) and she has gained her first professional development in this period. She has also gradually experienced how the particular science topics were taught, and how the needs of gifted students were met. Moreover, she participated in some in-service training activities such as introduction of the characteristics of gifted students and argumentation teaching method.

3.3 The Subject Matter and Topics Selection

The case of the study included three physics topics namely work/energy, simple machines and friction force. Physics was selected as a subject matter because the participant teacher graduated from physics department. It was assumed that the teacher has strong SMK and she combined SMK with general pedagogical knowledge successfully while teaching the three topics. According to the science teacher’s PCK literature, strong SMK can support development of PCK (Abell, 2007; Magnusson et al., 1999), and SMK and general pedagogy are an integral part of teaching (Shulman, 1986). Therefore, it was expected that the participant teacher reflected SMK skillfully in order to become more responsive to the needs of gifted students confronted with difficulties in learning the science concepts.

PCK is considered as a paradigm for researchers and each study has tried to complete a part of the puzzle (Abell, 2008). A science topic can be a part of the whole required to study by the researchers. There are different studies related to teachers’ PCK in terms of their aims, topics, and subjects for example, biology topics (Cohen & Yarden, 2009; Friedrichsen & Dana, 2005; Käpylä, Heikkinen, & Asunta, 2009; Tekkaya & Kılıç, 2012), chemistry topics (Aydın, 2012; De Jong, Van Driel, & Verloop, 2005; Demirdöğen et al., 2016; Park & Oliver, 2008; van Driel et al., 2002; van Driel et al., 1998), and physics topics (Etkina, 2010; Findlay & Bryce, 2012; Halim & Meerah, 2002; Nilsson, 2008: Seung, 2013). Researchers suggest that science teacher education requires more topic specific research to achieve the paradigm (Abell, 2008; Loughran et al., 2004; van Driel et al., 1998). In comparison to chemistry and biology, physics topics have received less attention especially in Turkish context (Aydın & Boz, 2012). Moreover, when physics topics were analyzed, researchers focused on the following topics: linear motion including concept of speed, velocity, and acceleration; thermodynamics including heat energy and temperature which were studied with pre-service physics teachers in the secondary school level (Veal et al., 1999), the topics of force and electric circuits with secondary school physics teachers (Loughran et al., 2004), the concepts of light, speed, force, heat concepts with pre-service teachers (Halim & Meerah, 2002), the topics of heat energy and temperature with experience teachers (Magnusson & Krajcik, 1993), the topic of force in floating and sinking with both pre-service and in-service teachers in elementary school level (Parker & Heywood, 2000), the topic of thermal physical phenomena with pre-service teachers (Sperandeo-Mineo, Fazio, & Tarantino, 2006), the topic of electricity and magnetism with experience teachers in the secondary school level (Eyüpoğlu, 2011). However, all of the studies are related to SMK or analyses only one or two PCK components, and they do not include the relationship between SMK and all PCK components. As a summary, in the science teacher literature, there are some studies related to physics topics mentioned above but they have not focused topic specific feature of PCK all components. Therefore, no topic-specific study in terms of PCK all components in the topics of work/energy, simple machines and friction force with middle school level, it formed selection criteria of the study topics.

The other topic selection criterion was that physics topics include abstract and complex concepts (Hammer, 1996), and they are considered to be difficult processes for students' understanding (Ahtee & Johnston, 2006). The topics of this study; work and energy, simple machines, and friction force take part in the unit of the force and movement in the 7th grade (Ministry of National Education [MNE], 2006) and they lead science teachers to deal with many challenges to enhance understanding of the concepts. The literature shows that there are many individuals (pre-service teachers and/or students) having misconceptions, pre-knowledge, or alternative conceptions about work and energy (Avcı et al., 2012; Çoban et al., 2007; Kruger, 1990; Trumper, 1998; Yürümezoğlu et al., 2009), simple machines (Marulcu & Barnett, 2013), and friction force and energy (Atasoy & Akdeniz, 2007; Hançer, 2007; Hope & Townsend, 1983; Kaplan et al., 2014). According to the above studies, students face difficulties in understanding related topics, and science teachers must deal with many challenges during planning, teaching, and evaluating the topics. Therefore, it was expected that the pedagogical challenges which was presented by the participant provided the researcher to obtain enriched data including pedagogical applications and the interactions between teacher and students.

Another topic selection criterion was to ensure having long term data collection process. In order to present a general profile of teacher's PCK, long term engagement should be employed with teachers and their interaction of students (Abell, 2008). Because teaching and learning activities include complex processes, they need time to be constructed by students or to be taught by teachers. For this reason, PCK is not easily understood and assessed (Baxter & Lederman, 1999). In this study, three physics topics (work and energy, simple machines, and friction force) were selected to better understand the participant teacher's PCK. Only one topic might not be sufficient to portray teaching segments including knowledge and abilities so that it can be difficult determine PCK and its components' interactions (Loughran et al., 2006).

According to the constructivist approach, when new knowledge is acquired by students, they involve in learning process where the new knowledge is constructed by prior knowledge arising from previous experience. In other words, previous learning is always the basis for future learning (Çakıcı, 2008). For example, learning or teaching any science concept is affected by the previous concepts or knowledge. If one concept is not understood very well, the meaningful learning of next concepts does not occur. In this respect, the succession of topics (work and energy, simple machines, and friction force) was selected from a unit to understand how any concept learned or not learned by students affects the teaching of next concepts such as better understanding of the concept of simple machines plays an important role in understanding the other concepts that come after it. For example, understanding only the change of direction of force in fixed pulleys facilitates understanding of force with a vector magnitude (Marulcu & Barnett, 2013). In this study, the succession of the topics helped the researcher determine the teacher knowledge of curriculum (teacher knowledge about concepts in the horizontal and vertical relationships) and knowledge of learner (knowledge of requirements for learning). This topics selection also provided the researcher with abundant examples in order to understand the interaction between KoIS and KoA.

Another issue of the three topics selection was to clarify the teacher’s STO. Definition of science teaching orientation is a controversial issue (Friedrichsen & Dana, 2005). According to the framework of this study, STO is defined that general teacher's view of teaching and knowledge of teacher's purposes and goals toward in planning, teaching, and evaluating of a specific science topic (Magnusson et al., 1999). It is also considered a subject specific PCK component. However, the researcher thought that STO might be changed from one topic to other topics and in order to understand the participant teacher’s STO, cart-sorting activity for each topic was prepared and investigated. Similarities and differences among cart sorting activities were presented in the finding chapter of the present study. In summary, the three science topics were selected to better clarify the teacher’s PCK and it components.

3.4 Description of Research Context

A private elementary school with its physical environment constituted the study context including gifted students both primary and middle school in Ankara. Gifted students were selected for this school by experts by using some general aptitude, competence, and intelligence tests. The school had a science and technology laboratory, and modern classrooms having computers, smart boards, and learning materials (posters, maps, graphics, etc.).

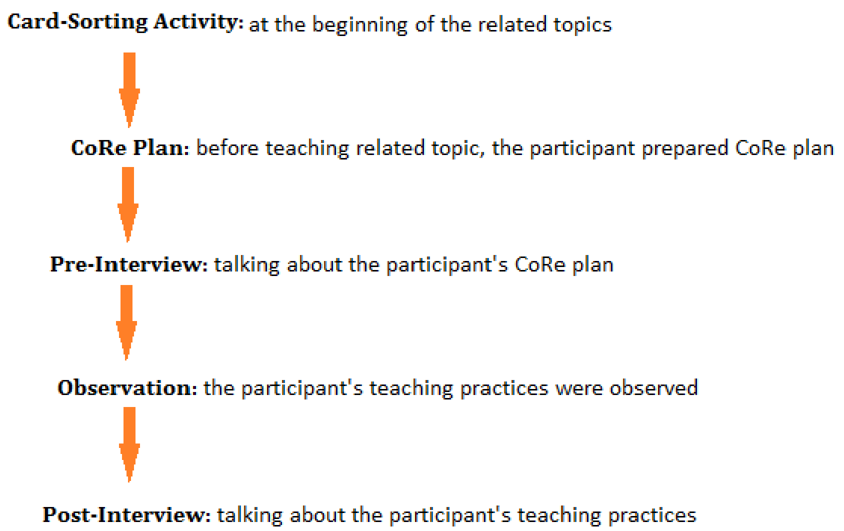
In order to offer educational opportunities, school administrations define giftedness in an amazing range in the gifted education literature. This range spreads from the top 1% to the top 30% in which students are selected for educational services based on the criteria (Gilman, 2008). This range has arisen from the definition of giftedness defined by professionals (Gagne, 2004). For examples, Marland (1972) has accepted the top boundary of giftedness between 3 % and 5 % in the population, Renzulli (2005) designates that the talent pools have higher performance on the above of 20%, and Gagne (2004) has identified gifted and talented individuals in the range of 10% (IQ score ≥ 120 equals mildly gifted, IQs≥ 135 equals moderately gifted, IQs≥145 is highly, IQs≥ 155 is exceptionally, and IQs≥165 is extremely). Within this respect, the school in the present study context has used a criterion which includes cut-off points IQs≥ 120 in order to identify gifted students by using WISC-III (The Wechsler Intelligence Scale for Children) (Wechsler, 1991).

The data were collected from the science teacher who taught science in seventh grade classroom, and there were twelve gifted students generally between 12-14 years old. The elementary science curriculum being used in this class was constituted by Ministry of National Education (MNE, 2006) as a program implemented across the country as part of compulsory education. In addition to science curriculum, each science topic or activity is enriched by the teachers and experts to meet the gifted students' needs.

The data were collected from the science teacher focusing on her science teaching, and interaction with gifted students while teaching the topics of work/energy, simple machines, and friction force in the real classroom context. Therefore, I observed the teacher's different applications, the interactions between the teacher and the students, and her PCK. The classroom context provided the researcher to obtain detailed information from both the participants and students because in-service teachers present more strong and meaningful PCK in real classroom settings than pre-service teachers (Abell, 2008; Lee, Brown, Luft, & Roehrig, 2007).

3.5 Data Collection

The aim of the study was to examine topic specific teacher PCK. It is difficult to find out the teacher PCK in detail and impossible to analyze teacher' teaching and students' learning using only one data collection technique in a short time (Baxter & Lederman, 1999). Science teacher PCK literature suggests that long-term observations, interviews of participants and using multiple techniques enhance the interpretation of the obtained data (Abell, 2008; Baxter & Lederman, 1999, Loughran et al., 2006). Therefore, qualitative research design provides many alternative data collection methods to obtain detailed and in-depth information about the case (Merriam, 2009; Yin, 2009).



This data collection process was applied separately for each topic; work and energy, basic machines, and friction force.

Figure 3.1. Data Collection Process

Figure 3.1 indicates data collection process used in the present study. In this study, multiple data collection techniques were used such as card-sorting activities, content presentation (CoRe), interviews, observations, and field notes. Detailed explanation about each data collection tool was presented in the titles listed below.

Table 3.2. The Relationships between Research Questions and Data Collection Tools.

Research questions and sub-questions		Cart-sorting activity	CoRe	Pre-interview	Observation	Post interview
Topic specific nature of PCK	STO	P	S	S	P	S
	KoC	-	P	P	P	S
	KoL	-	P	P	P	S
	KoIS	S	P	P	P	S
	KoA	-	P	P	P	S
Interaction of PCK components	Planning	-	S	P	-	-
	Practicing	-	-	-	P	S

P: primary data collection tool, S: secondary data collection tool

Table 3.2 summarizes the relationships between research questions and data collection tools. First research question and sub-questions represented by topic specific nature of PCK and second research question and sub-questions were considered under the title of interaction of PCK components in the table. For this study, each data collection tool was designed to reach a specific aim, and it was called primary (P) data collection tool. However, other collection tools provided additional evidence to support the interpretation of data, and they were called as secondary (S) data collection tools to answer related research question. For example, card-sorting activity and class observations were primary data collection tools in order to compare and contrast between the teacher belief and her teaching practices in terms of STO. In addition to primary data tools, CoRe, pre-interviews and post-interviews were used to discover the evidence about the teacher STO. On the other hand, other PCK components were examined through CoRe, pre-interviews, and post- interviews as primary data tools, and post-interviews served as secondary data collection tools to clarify differences between the teacher’s CoRe plans, and pre-interviews and her teaching practices.

3.5.1 Card-Sorting Activities

Card-sorting activities were used to find out the teacher’s science teaching orientation (STO). Science teaching orientation is teacher's general view of teaching and knowledge of teacher's purposes and goals toward in planning, teaching, and evaluating of a specific science topic (Magnusson et al., 1999). Card-sorting activities are a useful tool to determine and categorize the science teacher’s goal and purposes toward teaching a specific topic to students (Friedrichsen & Dana, 2003).

In this study, I used card-sorting activities to examine teacher's STO for three physics topics. The researcher prepared separately the scenarios about teaching work/energy, simple machines, and friction force. The card-sorting activity includes nine scenarios about each topic and six scenarios related to curriculum goals, affective domain, and gifted education. Before the formal teaching of each topic, the participant teacher was asked to categorize the scenarios into three groups. The first group cards involve teaching scenarios which reflect or are parallel with the teacher's instruction/teaching the related topic. The second group cards are not parallel with the teacher's instruction/teaching, and the last group includes scenarios which the teacher is not sure whether to match her teaching or not. After categorizing the cards, the teacher’s STO was analyzed with interview questions to obtain enriched and detailed information. Appendix A shows the card-sorting activities and interview questions.

While developing card-sorting activities, the literature was investigated about studies including STO (Aydın, 2012; Friedrichsen, 2002; Friedrichsen & Dana, 2003, 2005; Friedrichsen et al., 2011; Magnusson et al., 1999). Magnusson et al.’s (1999) PCK model provides nine STO types about teaching a specific topic. In order to elucidate the teacher's knowledge about science teaching and learning (goal of teaching science and characteristics of instructions), the nine STO types were prepared for each topic; work/energy, simple machines, and friction force. In addition to these nine scenarios, Friedrichsen and Dana (2003; 2005) suggested different orientations related to affective domain goals and general schooling goals owning to fact that the STO is complex teacher knowledge, and Magnusson et al.'s (1999) model is not enough to find out a teacher's STO. Therefore, I developed additional scenarios including general Turkish school goals, gifted education goals, affective domain goals and nature of science. In sum, there is certain knowledge and belief system affecting science teachers' practice and it is essential to consider all dimensions together when STO is analyzed (Friedrichsen et al., 2011). After finishing the development of card-sorting activities, expert opinion was taken from three experts to guarantee content validity, grammar, and wording.

After having completed the scenarios, certain additional interview questions were formed because only the classification of scenarios is not enough to obtain detailed information about the teacher's STO (Baxter & Lederman, 1999; Friedrichsen & Dana, 2005). Before the teacher categorized the cards, a few questions were asked about what the reasons and purposes of science teaching/learning are, how gifted students affect the selection of these purposes, and what the factors to distinguish her purposes from other schools are. Then, the cards were grouped by the participant, and the interview questions were conducted to find out detailed information about groups. Moreover, the teacher was asked to consider three groups in terms of gifted and non-gifted students. After finishing the card-sorting activities, the teacher's classroom teaching was observed to determine her STO as well. As a result, multiple data sources were used to find out the teacher's STO which were also suggested by the previous PCK studies (e.g., Friedrichsen, 2002). Three different card-sorting activities were also prepared and applied by following the above process for the three physics topics because STO may vary from one topic to another, and the teacher might have different goals and purposes while teaching the different topics.

3.5.2 CoRe (Content Representations)

Discovering teachers' professional knowledge is a difficult process. Traditional methods are not enough to portray PCK, and multiple data sources should engage in teachers’ PCK studies (Abell, 2008; Baxter & Lederman, 1999, Loughran et al., 2006). CoRe is one of the data sources to articulate and document teachers’ knowledge and applications. CoRe also allows researchers to obtain PCK an in explicit way because teachers express themselves (Loughran et al., 2004).

CoRe can be used as a lesson plan for teaching a particular science topic. There are two parts in the CoRe table, the column part includes science big ideas and/or concepts or issues which they think should be taught. The row part of CoRe involves eight questions related to teaching big ideas. Teachers are asked to answer the all questions before teaching, and in this way, teachers’ thoughts and knowledge related to big ideas can be obtained. CoRe enables teachers to notice their PCK by answering the eight questions as shown in Appendix B.

In the present study, the teacher was asked to prepare CoRe table for the topics of work and energy, simple machines, and friction force. The teacher selected four big ideas which were work and energy, kinetic and potential energy, simple machines, and friction force. The teacher prepared each CoRe plan before teaching related topics and the researcher interviewed the teacher about each CoRe plan to obtain detailed information about the teacher’s thoughts and knowledge.

3.5.3 Interview

Because in qualitative case studies, interviews are the main tool to collect the data generally focuses on individuals’ problem or behavior. A participant who is well-informed about a problem or behavior can provide valuable information which can be used to focus on other data sources (Yin, 2009). Interview is also used to obtain information about individuals’ experience, behavior, emotions or perception of social phenomena which are not directly observed (Merriam, 2009).

In this study, two types (pre-post) of semi-structured interviews were carried out to gain data from the participant. Pre-interviews were conducted after the teacher prepared the CoRe plan related to science topics. Organizing CoRe plan is difficult and time consuming for teachers based on the literature (Loughran et al., 2006) and pilot study of the researcher, so the participant teacher sometime did not fill out her CoRe plan in detail. In order to handle this situation, I interviewed with the participant to elaborate on her answers after analyzing her CoRe plan. Moreover, the post-interviews were conducted after observing her teaching of the related science topics. I observed the teacher with reference to her CoRe plans and I noted some students' and the teacher's behavior or event during her teaching in the classroom. If there were some differences or mismatches between the CoRe plan and her teaching, and I noted them and asked the teacher in the post-interviews.

While developing the interview questions, the questions in the CoRe plan (Loughran et al., 2006) were used as an interview protocol including clues to be followed in that order to prevent confusion during the interviews. The interview protocol helps form semi-structure questions which elicit the views of the teacher on her teaching and other ideas that the teacher did not mention in the pre-interviews (Merriam, 2009). After completion of the above process, expert's opinion was obtained from three experts to check the content validity, grammar, and vocabulary of the interviews questions. After receiving feedback for the questions, the pilot study was conducted with one elementary science teacher in the science and art center. Each interview (pre-post) was recorded to form databases.

3.5.4 Observation

In the educational setting, observation is often used to describe the behavior of related to phenomena and reveal the underlying effect of the behavior in the classroom (Marshall & Rossman, 1989). Observation takes place among the primary sources because it allows researchers to investigate social events in nature (Merriam, 2009). For example, when a curriculum is analyzed by using observation in the school context, it provides invaluable evidence about the teacher's applications (Yin, 2009).

Due to the nature of PCK, studies include teachers’ knowledge, ideas, and presentations about as a specific topic, and observation has often been used to interpret teachers’ behavior in a more accurate and holistic way (Baxter & Leadermen, 1999). Observations are generally combined with interviews in order to capture elements that did not come up in the interviews. Thus, researchers can capture the desired or unusual behavior during observations which helps form a more complete picture, and observation of the teacher in the classroom is necessary to gain a holistic view about science teachers' PCK.

In the present study, I observed the teacher’s class while she was teaching work and energy, simple machines, and friction force as a non-participant observer. Each class observation lasted 40 minutes (three class hours per week) and I used the observation protocol that I developed by using Magnusson et al.’s (1999) PCK model and its components. It helped the researcher to take notes about the teacher's applications, such as curriculum materials, instructional strategies, student's responses to applications, and students' misconceptions. One of the aims of taking note was to obtain evidence to ask the teacher about her instructional behavior during the post-interview (Merriam, 2009). The classroom environment had a dynamic and the teacher's plan generally mismatch with her teaching. The pedagogic behaviors that were outside the plan was very important to determine PCK research while conducting class observations.

In this study, during observation, I recorded each class for 40 minutes (20 classes) after the participant was informed and the permission was taken from her. 20 class observations were a long term observation in order to better understand the teacher’s PCK. In addition to descriptive nature of her PCK, the long term observation, nearly seven weeks, help the researcher had better understand about the relationships among PCK components. After analyzing all data arising from observations, interviews, and other tools, a more comprehensive picture about the teacher PCK was achieved (Abell, 2008).

3.6 Pilot Study

After finishing development of the data collection tools, I conducted an initial research to check my data collection process. The pilot study helped reconsider the data collection plan and developed to detail the protocol of real study (Yin, 2009).

The pilot study was conducted with a science teacher who is responsible for teaching gifted students in the science and art center which is explained in the participant selection part. The participant had five-year-teaching experience with gifted students and five-year-teaching experience with non-gifted students at the elementary level. I had a chance to experience in conducting PCK research with an experienced teacher. I used all data collection tools mentioned in the data collection section and conducted the observation for a month (3 class-hours per week). The science and art center is a different context from the compulsory education. The teacher selected the teaching topics and organized activities based on gifted students' abilities. During the data collection, I observed four science activities each week, and each activity has different subjects and topics; (1) the electric circuit, current, electric conductivity in liquid medium, (2) force, buoyancy and surface relationship, (3) density and buoyancy, and (4) structure of matter, physical and chemical changes, and chemical reaction. The teacher prepared each activity to teach the conceptual understanding of related topics and to enhance special abilities of gifted students.

When it comes to analyzing the data, the center's STO was different from regular elementary schools. Since there was no curriculum supported by Ministry of National Education for gifted students, the participant teacher has to prepare enrichment activities for development of students' abilities by using elementary or secondary curriculum concepts or materials. The participant's enrichment curriculum knowledge could be recognized during this pilot study. A remarkable result was that the characteristics of gifted students (such as quick and easy learning related to science concepts, asking difficult and interesting questions, and extending enriched activities and discussions) shaped the teacher's applications. Since the students could learn quickly and gain the reasoning of underlying scientific phenomena, they needed to engage in enriched activities having upper grade concepts and materials.

Another result was related to the component of teacher's knowledge of assessment. According to the center's vision, grading of students by using traditional assessment techniques (quiz, written examination, or multiple choose test) to evaluate conceptual understanding was not considered by the teacher. The focus of assessment in the center was to determine students' special abilities measured by the teacher observations.

In light of the above results, I recognized that the characteristics of gifted students and the teacher's enrichment curriculum knowledge could affect teacher's teaching. The knowledge of assessment was not considered by the teacher, and she used informal assessment techniques. After the pilot study, I refined the data collection tools, interview and observation protocols. I also decided to conduct the main study with a compulsory elementary school because I would be able to collect the data from the teacher and analyze data by including all five components of PCK. As a result, the pilot study was useful for me to refine the necessary changes based on elementary school context and to increase familiarity with gifted students. The data collecting and analyzing process provided me to increase my experience as a researcher.

3.7 Data Analysis

Due to the nature of qualitative research, multiple data tools were used in this study to portray detailed information about the science teacher's PCK and its components. Data analysis of a case study is a process which includes limited units where intensive analyses and comparisons take place in a holistic way (Merriam, 2009; Patton, 2002). First, the collected data must be arranged, manipulated, and prepared to form the data bases which help the researcher in coding and forming themes inductively and deductively to interpret the evidence to find out the answer of research questions (Yin, 2009). In this study the data analysis involved three analyses approaches based on research questions. The analysis process was explained under the following titles.

3.7.1 In-Depth Analysis of Explicit PCK

The aim of the study was to investigate the nature of a science teacher' PCK and its components based on Magnusson et al.'s (1999) PCK model. After preparing the data for analyzing (the transcription of audio records of pre-post interview, classroom observation, card-sorting activity), I coded the data bases deductively to follow Magnusson and colleagues' model. A qualitative research generally starts to code with deductive way because the codebook consists of the codes coming from the literature (Patton, 2002). Thus, I started to code the data by using open coding technique in terms of PCK components; science teaching orientation, knowledge of curriculum, knowledge of learner, knowledge of instructional strategies, and knowledge of assessment. While making detailed analysis, new codes are discovered inductively such as codes related to enrichment curriculum or characteristics of gifted students. The data were analyzed using NVivo qualitative data analysis program which is a computer-assisted tool and helped coding and categorizing a large number of narrative texts (Yin, 2009).

After determining the codes, the categories were formed by following PCK components and sub-components for the three topics. For example, the component of STO was analyzed by using the card-sorting activities, class observations, and interviews for each topic. According to the card-sorting activity, I coded and categorized the teacher' orientation in terms of scenarios and classroom observation which provided the evidence to compare the teacher's ideas about STO and her applications. Some mismatches were recognized between the teacher's ideas about STO and her classroom implementation. During post-interview, I had a chance to discuss with the participant about her mismatch STO. In a similar manner, each component was analyzed, and the examples of detailed information were further presented in the result section.

3.7.2 Content Analysis

Content analysis is a technique allowing researchers to investigate human behavior not directly observed (Fraenkel & Wallen, 2009). Content analysis also seeks to discover repetitive words or categories of qualitative data in order to reduce the number of categories, thus it enables researchers make inferences (Patton, 2002). The aim of using this content analysis in this study was to determine interaction of PCK components while the teacher was planning and teaching in the three topics. By this means, findings were used for the answer of the second research question and its sub-questions. The question aimed to find out how PCK components interplay in teaching the topics of work/energy, simple machines and friction force.

Interaction of PCK components was defined that two or more components were interplayed together in order to attain teacher's goals and purposes on the planning or teaching practices of any science concepts. In other words, the interaction of components meant that the teacher uses a component in order to handle students' misconceptions or to enhance their conceptual understanding using another component. For example, knowing that she has group made up of gifted students, the teacher devised enriched activities to cater for the special needs of such students. She employed activities which require students' use of argumentation instructional strategy. In this example, there are two interplays among STO-KoC-KoIS. The first interaction is between STO and KoC because the teacher's aim is to prepare enriched activities by using upper grade concepts or materials. The second interaction is that both the teacher and her students were involved in an activity supporting argumentation technique.

Before starting content analysis, I had obtained codes emerging from in-depth analysis of explicit PCK section such as STO (teacher goals, didactic, process, inquiry, hands on, etc.), KoC (curriculum objectives and materials, enrichment activities, and curriculum limitations), KoL (prior knowledge, pre-requirement, alternative conceptions, and characteristics of gifted students), KoIS (topic specific instructional strategies, students-centered and teacher-centered instructional strategies), and KoA (knowledge of what to assess and how to assess). These codes helped diagnose the interactions of the teacher's PCK components in her planning and teaching practices. In order to portray the interactions of PCK component on the teacher planning stage, I used the teacher's CoRe lesson plans and pre-interviews. On the other hand, I analyzed only her class observations and post-interviews to determine the interactions of PCK components during her teaching practices.

In order to start content analysis, the researcher should determine categories among PCK components from literature, and then, discover the interaction categories in the text (Fraenkel & Wallen, 2009). In this respect, I used the interaction categories developed by Park and Chen (2012) and Aydın et al. (2015) to diagnose interactions among PCK components. I modified the categories in the study context and designated new categories derived mainly from the direction of the influence of the characteristics of gifted students.

In the planning section, I began the content analysis with discovering the interaction PCK components and I generated 21 interaction categories showing possible interactions (Please see Table 4.8 in Chapter 4 for the categories and their explanations). After analyzing the data set, I realized that the interaction categories arose from five pedagogical needs such as the teacher's goals for teaching, using a component informs to select another component, pre-requirement of instructional decision, characteristics of gifted students, and multiple interactions. The pedagogical needs were explained in the finding chapter in detail.

In the teaching practices section, I discovered 10 interaction categories (Please see Table 4.9 in chapter 4). After finishing content analysis, PCK maps were constructed for each topic during both planning and teaching procedures, which explained in the next part of constant and comparative method.

3.7.3 Constant Comparative Method

The interaction among components was used to construct PCK maps for each teaching topic by using constant comparative method. Each interaction category was compared and contrasted with the categories of Park and Chen (2012) and Aydın et al. (2015). While a PCK map was constructed about the relevant topic, another topic map was built in a similar process comparing the first map and the second map. This is a repetitive process where the spiral motion proceeds from concrete data to more abstract concept or theory. The spiral motion takes place to compare data and data, data and category, category and category, and category and concept (Bryant, 2013). The aim of the constant comparative method in this study was to compare the interaction PCK component with categories, compare categories with categories, and construct PCK map with inductive technique. This analysis continued until the data saturation where a new category or interaction was not obtained from the data bases (Cresswell, 2007).

PCK maps presented the teacher's pedagogical decisions and behaviors in a clear way. Each PCK map includes the decision-making segments (maps constructed according to the data collected in the planning process) or teaching segments (maps constructed according to the data collected during teaching practices). For example, Figure 3.2 shows a part of the planning PCK map involving four decision-making segments, and on this figure, there are numbers starting from one to eight. The numbers on the PCK maps represent the order of the teacher's pedagogical decisions or behaviors. In other words, the teacher started to design her CoRe lesson plan with the questions "What do you intend the students to learn about this idea?", and "Why is it important for students to know this?" The teacher's answers to these two questions were related to the first three interactions shown on Figure 3.2. The teacher responded to the questions as follows: "providing the students with the experience of conceptual understanding of kinetic and potential energy and enhancing the students' abilities; creativity, reasoning, and thinking, and providing the students with enriched activities". I coded the first three interactions as a decision making segment. The second decision making segment included the fourth (the gifted students need to engage in enriched activities) and the fifth (lack of students' prior knowledge blocks the understanding of science concepts) interactions. The sixth interaction arose from the teacher's answer "the teacher goals were to enhance the students' abilities while they were learning kinetic and potential energy topics". The seventh interaction included four PCK components and emerged from the answer of CoRe question "What else do you know about this idea (that you do not intend students to know yet)?" The teacher planned the teaching of the formula of kinetic and potential energy as an enrichment activity. However, she thought that the differences between unit and symbols in the formula could lead to learning difficulties (the interaction between KoC and KoL is number seven in the decision-making segment of number four). In order to handle the possible learning difficulties, she planned to explain the differences and English meaning of each symbol (KoL-KoIS). Then, she thought to assess whether her explanation would be enough to understand the differences (KoIS-KoA). The eighth interaction explained that the enriched activity of the formula of kinetic energy included an alternative conception (velocity and speed are the same concepts), and it might cause a learning difficulty (KoC-KoL). In order to handle this, the teacher designed an instruction by utilizing a particular instructional strategy (KoL-KoIS). The seventh and the eighth interactions formed other decision making segment, and it had more complex pedagogical decision making than the prior segments. To sum up, the interaction PCK components were coded and decision making segments were categorized in the way mentioned above. Each segment came together to constitute PCK maps while the teacher was planning her lessons.

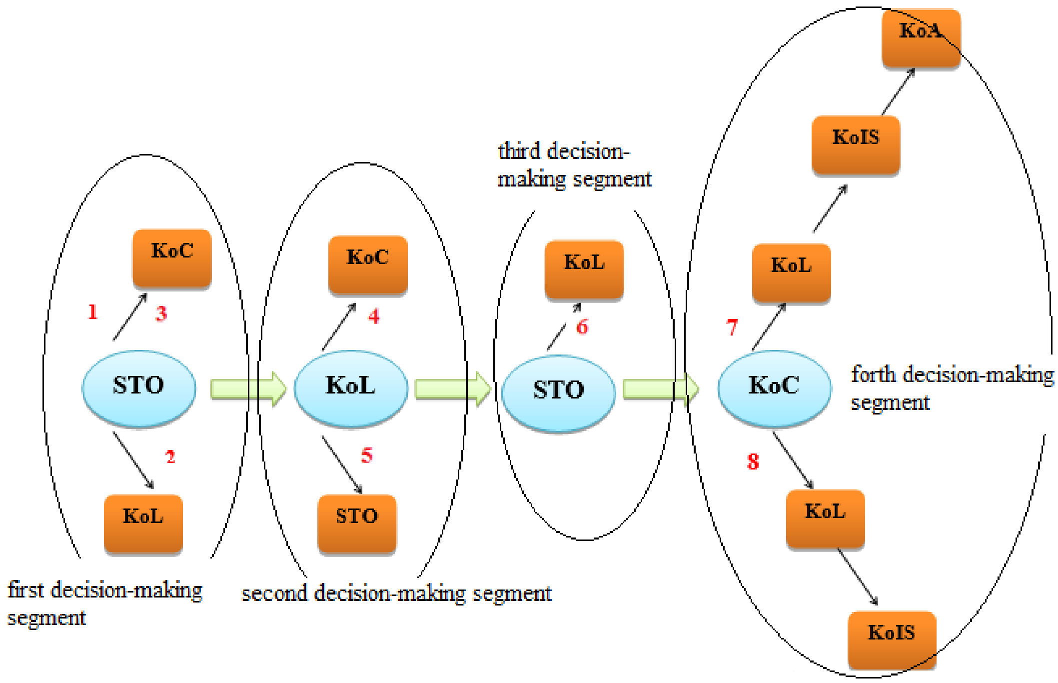


Figure 3.2. A Part of PCK Map during Planning Process

The large components in the middle of maps were used to initiate the interactions which were derived from some specific reasons. These reasons were explained in the finding chapter in detail. For example, in the first decision making segment in Figure 3.2, STO was an initiative component because the teacher reflexed her goals and purposes. On the other hand, second segment included KoL component and the task of KoL was to fit pre-requirement for learning or to meet the needs of gifted students. The fourth segment component was KoC including concepts or applications to lead learning difficulties and responsible for to start the interaction to handle learning difficulties, which required specific instructional strategies or assessment.

As seen in Figure 3.2, the big arrow marks appearing among decision-making segments don't indicate any relationships or interactions between prior segment and next one. They only show the order of the segments.

Different from the teacher's planning PCK maps, when constructing of teaching practicing maps, I analyzed the teacher's classroom observations and post interviews. Firstly, I determined the interaction categories shown in Table 4.9. Secondly, I formed the teacher's teaching segments (they were called as decision making segment in planning PCK maps) from the teacher pedagogical behaviors, which appeared during all the stages of teaching process of each topic. To illustrate, Figure 3.3 shows the interaction of PCK map during the teacher's teaching the topic "work and energy". The first teaching segment includes eight interactions. The teacher started the lesson with questions to assess students' prior knowledge or to determine students' alternative conceptions, which were coded as KoIS and KoA. The second interaction was observed to make abstract concepts more concrete by using specific examples or use particular instructional strategies to handle learning difficulties. After that, the teacher lectured the intended concepts (KoIS-STO) and she offered enriched activities to the students (KoIS-KoC). In the second teaching segment, the characteristics of gifted students affected her teaching through more questions arising from enriched activities, and the teacher tried to explain each of them (interaction number is nine). The last teaching segment involves two interactions. One of them is related to using particular instructional strategies to handle learning difficulties, which is shown in the 10th interaction. On the other hand, interaction 11 has more complex interactions than previous. In order to make assessment, teacher asked the questions. Then, learning difficulties occurred. So as to handle those difficulties, teacher revised questions or explained them. All the teacher's behaviors are represented by the 11th interaction.

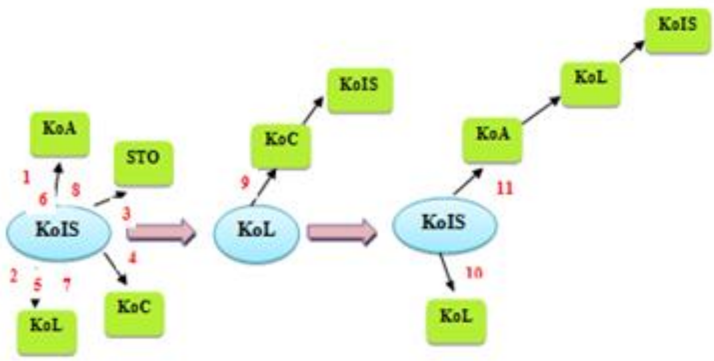


Figure 3.3. A Part of PCK Map While Teaching Practice

Similar to planning PCK maps, the large components have similar characteristic in the teaching practicing maps. The number of the interactions shows the order of the teacher's pedagogical behaviors from the beginning to the end of the topic. Moreover, the big arrow marks (→) as seen in Figure 3.3 does not indicate any relationships or interactions between prior teaching segment and next one.

In the science teacher education literature, there are a few researches investigating explicitly the interactions of science teachers PCK components such as Park and Chen (2012), Aydın and Boz (2013), Aydın et al. (2015), and Akın (2017). Each study used the pentagon model of PCK developed by Park and Oliver (2008) to portray the interactions among PCK components. Figure 3.4 shows an example of interaction pentagon model map's framework (Figure 3.2 and 3.3 represented the interaction maps' framework of the current study).

According to the pentagon model, these five components have equal values and features and they can interplay with each other separately. While constructing the pentagon PCK map, researchers first determine the interaction categories by using content analysis and separate participant teachers' teaching into pedagogical episodes or teaching segments. Each episode or segment has varied kinds of interactions based on the nature of the topics, and teachers' knowledge and applications such as KoL-KoC, KoA-STO, KoIS-KoL, etc. After determining the interactions between two components, the frequencies of the interactions are calculated. The numbers on the straight lines represent the frequency of the interaction between two components. For example, number 6 shows the frequency of interaction between KoL and KoIS, and number 5 shows the frequency of interaction between KoIS and KoC. On the other hand, the numbers in the circles including components show the total number of interactions in which one component connects with the other four components.

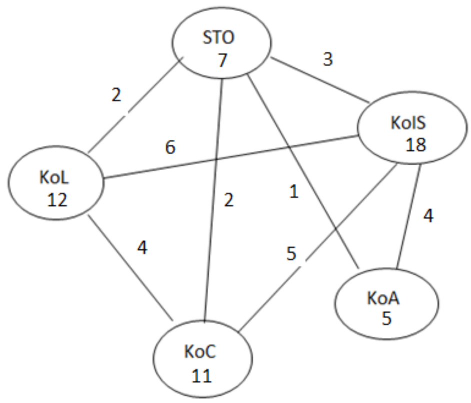


Figure 3.4. An Example of Pentagon Model Map

For example, KoC has a total of 11 interactions; KoC-KoL is 4, KoC-STO is 2, and KoC-KoIS is 5. To sum up, a PCK map is created following the steps above mentioned. The map might represent the interaction of a science teacher's PCK while teaching a particular topic or teaching segments. Moreover, researchers might compare and contrast different teachers' PCK maps or one teacher's PCK maps including a few different topics in order to determine which teachers have strong PCK or in which topics the teachers reflected more PCK. The map has more number of interactions and more kinds of interactions, it has stronger PCK. On the other hand, if a map has limited interactions with others or weak connections including few interactions with others, this map reflects that corresponding teacher has naïve PCK.

In this study, I used the interaction categories driven from Park and Chen (2012), and Aydın et al. (2015), and I also utilized two different mapping approaches (1) the study mapping approach was designed by researcher as illustrated in Figure 3.2 and 3.3, and (2) pentagon model mapping approach was developed by Park and Chen (2012). I added the two mapping approach for each topic and sub topics, however, I interpreted the data results based on the study mapping approach. In other words, I did not use pentagon model while interpreting and discussing related data because I believed that the study mapping approach provided more detailed information than pentagon approach to portray the participant teacher PCK. In doing so, I presented separately where each interaction was happening in terms of planning and practicing process (as illustrated in Figure 3.2 and 3.3). There were some reasons why I did not chose the pentagon model. The first reason was that the pentagon model provided limited information about the teacher PCK in the present study. When looking at the pentagon model (see detailed in Figures 4.15, 4.16, etc.) to portray the teacher's PCK, the interaction maps explains the number of interactions and weak or strong interactions between two components. However, with this study interaction maps, readers can see the interactions both in decision making segments and in teaching segments during all the stages of the lessons. The second reason was that pentagon model only shows binary interactions such as KoL-KoC or KoIS-KoA. However, I had some data including binary, triple, quadruple or even more interactions. Thus, the pentagon model limited our data to present all interactions in detail. The third reason was that pentagon model does not show teachers decision making and teaching process or teaching episodes and segments because it is the sum up of total interactions, namely, it is a summary of the teacher behaviors or knowledge. However, PCK maps of the present study show the teacher behaviors or decision making step by step during teaching or planning process. In other words, readers can easily understand each of interactions without explanation of codes and categories.

This study mapping approach also showed the interactions between similar components in planning process. For example, KoL-KoL means that it is difficult to deal with misconceptions because of characteristics of gifted students. In this interaction, sub-component of characteristics of gifted students was linked to another sub-component of knowledge of students' misconceptions and learning difficulties. Another example appeared in the same interaction of KoL-KoL which means that the students have knowledge about upper grade topics because of characteristics of gifted students. In this regard, the sub-components of knowledge of students' pre-requirements and knowledge of characteristics of gifted students interact together. Contrary to two examples, another interaction was seen in the KoC-KoC in which the teacher considered the curriculum limitations as enriched activities. In this interaction, knowledge of curriculum and knowledge of enrichment curriculum interacted together.

Finally, this study mapping approach provided more detail information about PCK component at each stage of planning and teaching practices. We can understand where and why each component was used to interact with each other. Furthermore, when looking at the maps it can be seen where the teacher faced pedagogical difficulties, the effect of students on teacher teaching, and which topics had more complex content than other.

3.8 Trustworthiness

Trustworthiness is related to accuracy and high quality of a qualitative study. There are many definitions or strategies to assess the accuracy of a study (Cresswell, 2007). One of these strategies is explained by Lincoln and Guba (1986), and includes "credibility, transferability, dependability, and conformability" (p.76-77). They are also correspondent internal validity, external validity, reliability, and objectivity respectively. In this study, Lincoln and Guba's (1986) set of strategies were followed to assess the validity and reliability.

3.8.1 Credibility

The aim of the qualitative research is to investigate a problem or social issue in the real context with its validity, which meaning that phenomena are accurately identified and described (Marshall & Rossman, 1989). In other words, validity is related to how the findings of the inquiry are consistent with reality and the nature of the qualitative research. For taking this consistency into account increases the quality of inquiry because researchers collect the data with first-hand experience and interpret the reality (Merriam, 2009). There are some techniques suggested by researchers (Merriam, 2009; Patton, 2002; Yin, 2009) to ensure a case study has valid findings and interpretations. In this study, four approaches were followed to increase the credibility: triangulation, peer debriefing, member checks, and long-term observation.

The first strategy is triangulation combining multiple rival supporters to answer the research questions. The assumption of the triangulation is that only one method is not adequate to reveal the rival explanation of the phenomena. Using multiple methods enable researchers to find out the different features of the reality. There are four types of triangulation; methods triangulation, analyst triangulation, sources triangulation, and theory/perspective triangulation (Patton, 2002). The three types of triangulation (sources triangulation, analyst triangulation, and method triangulation) were used to increase credibility of this study. Data triangulation was used through multiple data from the case such as card-sorting activities, CoRe, pre-post interviews, and classroom observations. Using multiple data had two advantages. One was that one data result was compared and contrasted with another data results. To illustrate, the pre-interview was compared with the observation, and the consistence between two data tools was checked. The second advantage was that there was sometimes mismatch between the results of two data tools, and the difference enables researchers to gain rival insight to reveal the meaningful answer to the problem (Patton, 2002).

The second type of triangulation is the investigator/researcher triangulation to ensure the findings of a study. The aim of the technique is to remove the bias or untrue interpretation represented by one researcher. In order to achieve this, the same data is collected by multiple researchers and analyzed by each researcher separately. Then, each result is compared and contrasted in order to reach a consensus (Merriam, 2009). In this study, one researcher joined the study during classroom observations and the two researchers collected the data by using the observation protocol. The second observer was a science teacher in the same school and he was familiar with the school context and the students. He was also a graduate student in the elementary science education department and his interest area is technological pedagogical content knowledge. Thus, he is knowledgeable about PCK and its components. He was also informed about the process of the inquiry, that was, the data collection protocols as to how to observe the teacher's class before beginning the observation. Forty percent of the total classroom observations were conducted by two researchers. After observations, the observation protocols were analyzed by each observer separately and the results were compared and contrasted to arrive at a consensus about discrepancies resulting from the observations. All the observation protocols were analyzed in detail. Moreover, while analyzing data sets, additional two researchers participated in the data analyses process. These two researchers are knowledgeable about science teachers' PCK, and the first researcher helped me code in order to determine the participant teacher' nature of topic specific PCK. Another researcher played an important role while constructing the interaction PCK maps. To sum up, three different researchers, except me, engaged in this study, and the values of interrater reliability were explained the next part, dependability section.

The last triangulation is the method of data analyses. This study was involved in three analyses strategies such as in depth analysis of explicit PCK, content analysis, and constant comparative method. In depth analysis was used to code all data bases in order to elicit the teacher PCK components. Content analysis method served to link one component to others which was determined in depth analysis method. While analyzing the data by content analysis, the researchers had an opportunity to check the coding results of in depth analysis method. In a similar way, constant comparative method facilitated to combine the interaction categories arising from content analysis method and to generate PCK maps by comparing and contrasting each interaction category and PCK maps. As a summary, the three analyses methods acted in a holistic way to reach complete picture of the study. In other words, the analyses methods have enabled the researchers to reach from many codes to several maps.

The second strategy is peer debriefing to increase the credibility of the study. Peer review or debriefing is an external check process to take help from other researchers for analyzing and interpreting the data (Cresswell, 2007). In this study, one researcher was invited to give support in coding data, categorizing the codes, and interpreting the data analysis process of the study. The peer researcher has experience in qualitative research and PCK. His contribution of analyzing and interpreting the data helped to increase the validity of the study.

The third strategy is member checks used commonly to increase internal validity. Member checks or responded validation means that the participants give feedback concerning the results of the study. It is also the most important practice in preventing the findings from misinterpretation (Merriam, 2009). In this manner, the results of the study including data, categories and interpretations were reviewed by the participant upon whom she gave feedback concerning the accuracy of the data. After her review, we agreed with the participant about the findings of the study.

Prolonged engagement and long-term observation were the last strategies to establish the credibility of this study. Prolonged engagement provides to build trust between the participant and the researcher, to gain more information about context, and to check the misunderstanding coming from researcher inferences (Creswell, 2007). In this study, while the teacher was teaching the three topics during the two months, I observed her classroom activities and teaching behaviors. I talked with the participant and the students about teaching and learning science topics, and school context to obtain more information.

In summary, according to the qualitative researchers, there are some strategies to ensure the credibility of a case study as mentioned above and at least two of such strategies should be used (Creswell, 2007). I was strictly engaged in four types of strategies (triangulation, peer debriefing, member checks, and long-term observation) and the detailed description of the methodology of the study to establish the credibility of this study. Researchers' experience and training are also important concern in conducting a high quality case study (Yin, 2009). In this respect, the researcher has been familiar with qualitative research and science teacher PCK. He has experience as a research assistant with pre-service science teachers for six years in the science methods course, practice teaching course, and other graduate courses to help enhance students' PCK. The pilot study also provided the researcher with valuable information about designing and conducting the main study.

3.8.2 Dependability

Dependability is related to minimizing the mistakes and biases and it focuses on the reproducibility of research findings in a study (Yin, 2009). A study sometimes can give dissimilar results in social science owing to fact that the human behavior is unstable. Therefore, it is important to answer the question of how much the results of the study coincide with the data collected during the study (Merriam, 2009). In order to answer this question in present study, some strategies suggested by the researchers such as using case study protocol, forming case study data base (Yin, 2009), triangulations, peer examination, researcher position, and detailed description of the study methodology (Merriam, 2009) were used to increase the dependability of the study. The two researchers were also engaged in data collection process such as coding and categorizing the data, and classroom observations. The interrater reliability was calculated by using a formula (Miles and Huberman, 1994) to find out evidence for reliability. The interrater reliability for the data coding (cart-sorting activities, CoRe plans and interviews, and observations) was 84%. Moreover, the two researchers were engaged in the classroom observations and the data were collected by the observation protocol. The interrater reliability of the observation protocols was 85%. Finally, while the constructing of the PCK maps, the two researchers also coded separately the related data and its reliability was 79%. After calculating of reliabilities, the discrepancies were discussed by the researchers and the agreement was revealed.

The discrepancies were handled by reaching a consensus, and then the codes were either accepted or removed from the study. The following events were a few examples of overcoming consensus process;

1. The teacher's opinion about her students' attitude toward the unit of force and movement led to a mismatch among researchers while engaging in depth-analyzing process. One researcher coded the teacher sentence "the students had prejudices or bias about the force theme, and they did not like this topic" as KoL. Whereas other researcher believed that this sentence was related to teacher general opinion and no need to code as KoL. Therefore, we removed this sentence from KoL category.

2. The following sentence led to appear discrepancy between inter-coders. The teacher evaluated her students' lab performance about lever topics and she appreciated the performance of the students with this sentence "Even high school students could not be successful in this experiment". This sentence was coded in different perspective by the researchers. One coded it as KoL in terms of high school level whereas the other coded it as KoC. After discussion this mismatch, the researchers agreed to remove this sentence from code data bases.

3. One example of discrepancy appeared in the evaluation of the students' performance in gears and hoops topics. After completing the introduction of topics, the teacher did not practice any problems on the board. Rather she distributed the handout including multiple chooses test in order her students to gain better understanding related topics. Then, the students began to solve each test item. However, some items led to appear difficulty for some students and the teacher was interested in explaining the related problem for that student. Stated differently, the teacher did not explain all questions on the board, and she focused on only test items including difficulties. Therefore, this process provided to save time. One researcher coded this teaching pedagogy as new type of assessment strategy. However, the other did not accept this code because he believed that while interviewing the teacher about this pedagogy, the researcher had affected the teacher to accept that this pedagogy was a strategy. Namely, there was a bias arising from the researcher in

terms of this pedagogy. So we did not accept this code as a new instructional technique.

4. Some codes were not realized by the researcher when interview data set was coded. These codes were related to generally the characteristics of gifted students and enrichment curriculum. The students asked so many questions including upper grade level content (does one object in a stable position have kinetic energy because of having electrons?, or one student imagined that he moved an object in his mind, so did this object perform any work?). The students asked the teacher to explain each of them. While coding the explanations, the researcher did not consider them as characteristics of gifted students, or not realize and skip them. Therefore, we discussed the reason of the code and then the researchers accepted the codes related to characteristics of gifted students.

5. While coding the teacher's class practices, the researcher coded the location in which the teacher practiced her teaching such as blackboard and around the teacher table as physical environment but the other researcher did not code. Therefore, we accepted this code as physical environment of classroom.

6. While the students were engaging the lab activities, they used some science process skills such as observation, data collection, categorizing the data in table, and discussion about the data results. The researcher coded as these skills arising from the teachers' pedagogies but the teacher did not present any pedagogy to explain the skills explicitly. Thus, we did not use this code.

7. The researcher coded the teacher classroom management performance. However, the teacher classroom management skills are related to the knowledge of general pedagogy. Therefore, we did not use these codes in this study including a topic-specific nature.

8. Some students could solve particular difficult problems in a one minute so this behavior was coded a characteristic of gifted students. However, other researcher did not realize this behavior. So we discussed it and accepted as a gifted students' characteristic. Another discrepancy appeared in the students' homework performance, and time spent period. The teacher checked the students' performance while they had been completing their homework in a particular time. However, this

behavior was not coded by the researcher as the teacher individual interest in her students. Therefore, we discussed and reach a consensus that it was related to teacher knowledge of individual assessment. Another example appeared in this teacher pedagogy in which the teacher did not move the next topics or problems until all students gain better understanding related topics. In this respect, this pedagogy was ignored by the researcher. After discussion related code, we reached a consensus as it is an individual interest of the teacher.

9. While determining interaction categories, some interaction codes such as STO-KoC (The aim of the teacher was to present enrichment activities by offering mathematical problems and formula) or KoL-KoC (enrichment activities were not appropriate for non-gifted students) were not realized by the researcher. Therefore, we needed to discuss them and we accepted these codes.

10. Some codes were not accepted in a topic specific nature so we removed them in the study. for example, KoL-KoIS-KoA-KoIS (the teacher thought that the students' alternative conceptions were able to determine with questioning and observation their performance, and verbal explanation was enough to handle of these conceptions in the planning process of kinetic and potential energy) this code was not accepted by the researchers because the teacher explanations for each components was not enough based on interaction categories.

11. While coding the interactions of PCK components in the teacher teaching, some discrepancies appeared among researchers, especially complex interactions such as KoIS-KoA-KoL-KoIS, KoL-KoC-KoIS, or KoIS-KoC-KoA-KoL-KoIS-KoL-KoIS. The researcher determined some interactions which was the half of teaching segment. The rest of the other part of the teaching segment was also coded as a different interaction such as KoIS-KoA (using questioning techniques as an assessment) and KoL-KoIS was the other part of teaching segment (the learning difficulties were handled by a specific instructional strategies). Therefore, the researcher was not able to connect KoA-KoL interaction (as results of assessment, the teacher realized an alternative conception or learning difficulties). So we discussed this connection and reached a consensus about the complex interactions.

12. Some interactions also did not realize by the researcher such as STO-KoIS (the aim of the teacher to present enrichment activities by offering mathematical formula) or KoC-KoL (some enrichment activities lead to learning difficulties). Those interactions were discussed to reach a consensus, and then we accepted these interactions.

3.8.3 Transferability

Transferability is related to external validity that emphasizes generalizing the results of the study to other populations (Yin, 2009). However, case studies, owing to their being qualitative, do not consider generalizing situations. The aim of a case study, therefore, is to obtain detailed information about social phenomena, not to generalize from one case to another. The question of transferability focuses on how we can apply the results of a study to other cases (Merriam, 2009). In order to enhance transferability in this study, rich, and detailed description of the study context was employed. In this regard, the teacher's experience and demographic information, the students, physical environment of the private school, and classroom were explained. Another element to increase transferability of the study was to develop a case study protocol including data collection processes and analyses procedures. Thus, the results of the study could be shared with other case studies including familiar context and science topics.

3.9 The Role of the Researcher

The researcher plays an important role in qualitative studies because the researcher involved in the data collection and analysis processes as a primary instrument. In order to increase the trustworthiness of a study, degree of the researcher participantness, revealedness, and extensiveness (Patton, 2002) should be explained. The participantness varies from full participant to complete observer depending on the aim of the study. In the present study, I assumed the role of a complete observer sitting a desk at the back of the classroom, and observed the teaching context. I did not involve in any teaching activities, or did not participate in any discussion.

The revealedness means to introduce the researcher's role the participant and school context. Before conducting study, the participant teacher was informed about the aim of the study and research process including data collection tools and the timeline in the teaching of three topics. After the teacher agreed to participate in the study, the schedules for the participant and the researcher were established for the inquiry. In order to become used to the school context and the students, I started to visit the school two weeks prior to actual observations. However, I did not collect any data at this stage. I was introduced to the students as a pre-service science teacher in order not to intimidate, and prevent the students from acting naturally in the classroom.

The last issue concerning of the role of the researcher is intensiveness-extensiveness. The school context was first visited in May 2014 and the participant teacher agreed to join the study which would start in November 2014. I visited the teacher several times to obtain demographic information and teaching strategies before starting. Thus, I gained much information about school context and we established rapport.

3.10 Ethical Issues

Frankel and Wallen (2009) suggest that three concerns should be considered to ensure ethical issues. The first one is protecting participants from possible harms. In this study, in order to assure the participant that the study would not affect her in a negative way, a permission form was arranged to submit to the Institutional Review Board and Ministry of National Education. After receiving the research permission (Appendix E) which confirms that the research would not lead to any potential harm to the participant and the students, the participant volunteered to join the study. Moreover, the names of the school and the participant were prevented to reveal by using pseudonym such as the school, the participant or the teacher, and the students during the data transcribing, analyzing and writing results. The second ethical concern is confidentiality of data. In this study, in order to ensure confidentiality of data, the participant was convinced that no one (except for the researcher, his advisor, co-coder, and co-observer) would reach the data of the study. The last ethical concern is deception. In order to protect the participant form deception in this study, the participant was informed about the aim of the study and the results of the data were presented to the participant at the end of the research.

3.11 Limitation of the Study

Due to the fact that the study has a qualitative nature, I studied the case study within some limitations. The first one was related to the transferability. In generally, the results of any case have limitation for generalizability of the results in other contexts, as teachers' PCK vary from context to context. This study was conducted with a science teacher of gifted students in a private school in Turkey with three physics topics. However, any teacher in Turkey or other countries may not represent his/her pedagogy while teaching three physics topics as well as the one in my study. However, the results of the study may be compared to and contrasted with the other studies' results, and the differences among the studies may be discussed in terms of the study context.

The second limitation of the study was the presence of the researcher in the classroom during observations. The students might be affected from the observer and they would not behave naturally. In order to handle this limitation, I, as the observer, was introduced as a pre-service teacher and I started to observe two weeks earlier for making them to be familiar.

The last limitation was about video recording during classroom observations. Due to the special statues of the school, I was not allowed to videotape of classroom practice. However, the teacher's behaviors and interaction with students are important for PCK studies. In order to deal with this limitation, a voice recorder, field note, and co-observer were used during classroom observations.

3.12 Timeline of the Study

The study timeline was given following Table 3.3

Table 3.3. Timeline of the Study

Date	Events
September 2013- December 2013	Design of the study
December 2013- February 2014	Development of the data collection tools (card-sorting activities, interview questions, observation protocol)
February 2014- April 2014	Getting permission
April 2014- June 2014	Pilot study in the Science and Art Center
June 2014- October 2014	Analyses of the pilot study, review of the data collection tools with regards to pilot study.
November 2014-January 2015	Conducting the main study in the private school
February 2015- June 2015	Preparing the data for analysis (transcription of the pre-post interviews and observation records) The data analyses with NVivo
June-2015 - November 2016	Writing results part of the thesis
November 2016 - June 2017	Writing conclusion and discussion section

3.13 Assumptions of the Study

This study has been conducted in line with some assumptions about nature of PCK.

1. The participant teacher has solid SMK while planning and teaching for three topics.

2. The participant teacher has enough knowledge in order to meet the educational needs of gifted students.

3. Because PCK is transformative knowledge, the participant has used other knowledge bases effectively (SMK, general pedagogy knowledge, etc.) to teach related topics.

4. The participant teacher reflected seriously and honestly her thought and beliefs while participating to answer all data collection process such as pre-post interviews, card-sorting activities, and CoRe plans.

CHAPTER 4

FINDINGS

In this chapter, I explained the findings of the data set including card-sorting activities, pre-post interviews, classroom observations, and field notes. The research questions shaped the titles of the findings. First I described the nature of teacher PCK and its components, and then the second research question took place in this chapter. In this study, the teacher's PCK was examined in terms of the three physics topics, namely, work and energy, simple machines, and friction force. While describing each finding title, the three topics were compared and contrasted involving the teacher's knowledge, views, and applications. Finally, each title has a summary paragraph explaining related research and sub research questions.

4.1 General View of the Teacher's Teaching

The participant teacher had a pattern in teaching of the second unit "force and motion" in the elementary science curriculum. Table 4.1 shows the teacher's applications in detail while each topic or concept was being taught. During the class hour, the teacher generally had four parts, namely, beginning of the lesson, introduction of the new concept, elaboration of the concept, and evaluation. In the first part of her teaching, she reminded the students the concepts covered in the previous lessons by using questioning or lecturing techniques. After a brief reminder, in the second part of her lesson, she introduced the new concepts by asking questions to check students' knowledge and alternative concepts. Then, in the third part of her lesson, she explained the new concept by using daily life examples, analogies, and many visual materials in the power-point presentation. She also gave formulas to provide more concrete awareness to enhance students' understanding related to the concepts and she had students take notes on important definitions and factors.

Table 4.1. Teacher's Teaching Pattern

Topics and concepts	Beginning of the lesson	Introduction of a new concept /engagement	Presentation and elaboration of the target concepts	Evaluation
Work and energy	Reactivates the previous concepts (e.g., springs)	Asks warm-up questions to determine alternative concepts	Lectures using examples and visual materials, Gives the formula of work, and dictates the concepts for students to take notes	Monitors class, asks questions, and gives handouts including multiple choice-test
Kinetic energy	Reactivates the previous concepts	Asks warm-up questions to determine alternative concepts	Gives a formula of $K={}^{1}/_{2}mv^2$, and examples	Monitors class, asks questions, and gives handouts including multiple choice-test
Potential energy	Summarizes the previous two topics	Asks rhetorical questions, and demonstrates to attract students' attention	Gives a formula of P=mgh, examples, and dictates the concepts for students to take notes	Monitors class, asks questions, and gives handouts including multiple choice-test
Conservation of energy	No pedagogical action	Gives example of pendulum, and asks questions	Gives more examples using power point presentation, and dictates the concepts for students to take notes	Monitors class, asks questions, and gives handouts including multiple choice-test
simple machines	No pedagogical action	Asks warm-up questions to determine alternative concepts	Gives daily life examples	Monitors class, and asks questions
Lever	Summarizes previous lesson	Engages students with an experiment aiming to discover the features of a lever	Guides a discussion of the experiment results, gives formula and examples, and dictates the concepts for students to take notes	Monitors class, and asks questions

Table 4.1. Teacher's Teaching Pattern (Continued)

Topics and concepts	Beginning of the lesson	Introduction of a new concept /engagement	Presentation and elaboration of the target concepts	Evaluation
Pulley	No pedagogical action	Asks questions and gives examples	Lectures and demonstrates using lab materials, and dictates the concepts for students to take notes	Monitors class, asks questions, and gives handouts including multiple choice-test
Hoist (block and tackle pulley)	Summarizes of the pulley	Asks questions, and gives daily life examples	Lectures, and gives examples	Monitors class, asks questions, and gives handouts including multiple choice-test
Inclined plane	No pedagogical action	Demonstrates, and asks question using lab materials	Lectures and gives formula and examples, and dictates the concepts for students to take notes	Monitors class, and asks questions
Spinning wheel (Wheel and axle)	Summarizes of the inclined plane	Explains using analogy between lever and spinning wheel	Lectures and gives formula and examples, and dictates the concepts for students to take notes	Monitors class, and asks questions
Gears and hoop	No pedagogical action	Asks questions, and demonstrates using model of gears and hoop	Lectures and gives formula and examples, and dictates the concepts for students to take notes	Monitors class, asks questions, and gives handouts including multiple choice-test
Friction force	Asks questions to help students to recall friction force	Engages students in an experiment to discover the relationships between weight and force, and surface area and force, respectively	Guides a discussion of the experiment results, and dictates the concepts for students to take notes	Monitors class, asks questions, gives handouts including multiple choice-test, and gives an achievement test end of the unit

The last part of her lesson was related to evaluation of students' understanding. She used informal (observation students, and questioning during her teaching) and formal (giving handout including multiple chooses test, or open ended test) assessment techniques at the end of her teaching.

The teacher generally displayed the pattern showing in Table 4.1 during her teaching of three physics topics. In order to find the answers to the first research question and the sub questions, her PCK analysis was explained in detail using the following order; STO, KoC, KoL, KoIS, and KoA.

4.2 The Findings of the Topic-Specific Nature of PCK

4.2.1 Science Teaching Orientation (STO)

According to Table 4.1, the data come from classroom observations and interviews; thus, it is seen that the teacher had complex STO in teaching three physics topics. She tried to activate all students by using questions. In order to make students understand the related concepts she was able to control their learning successfully. The students were also active participants during each part of the lessons because of their special gifted characteristics. The teacher stated the students' role in her class as follows;

> …If I always lecture the topics and they are asked to listen to me for a long time, they don't listen me…They become bored and you can even understand their boredom from their eyes. They need to engage in an active learning environment.
>
> …in this activities, the students are active and teachers are passive. Our purpose is to make students learn by experience in order to obtain meaningful learning. We know that they don't enjoy the lecturing… Thus, hands on activities are more appropriate for these students (card-sorting activity, simple machines).

Therefore, we cannot say that the teacher had teacher-centered orientation. She also tried to create a discussion atmosphere by using visual materials, examples, demonstrations which help students explain their thoughts about related concepts. Moreover, she conducted two inductive lab applications in order for the students to discover the related phenomena. The students used the lab materials and observed, measured, and discussed the results of the experiment about features of the lever and friction force. As a result, we cannot say that the teacher had a didactic orientation explained by Magnusson et al. (1999) which is about convey the SMK to the students.

In comparison Table 4.1, there are also results related with the card-sorting activities in which we observed some differences between the teacher's ideal goals and her practices in the classroom. The card-sorting activities include four parts of scenarios such as curriculum and school goals, work and energy, simple machines, and friction force. The first category of scenarios is related to curriculum and school goals abbreviated in C, referring to portray the teacher's STO about schooling, affective, gifted education goals, and reality of Turkish education system shown in Table 4.2 in detail, and all scenarios were presented in Appendix A. Due to the fact that the school has served gifted students; the teacher had different goals in addition to those of the elementary science curriculum. In addition to C1, C2, and C3 scenarios which reflect goals of the gifted students' education, the teacher also selected C2, C3, and C5 scenarios in order to reflect her goals. The teacher considered determining gifted student's special abilities and enhancing those abilities in addition to goals of the elementary science curriculum. Moreover, she stated following goals;

> …In addition to science curriculum, we use enriched curriculum where we design and plan different activities including watching a video or documentaries, playing games, and doing a field study. In school, there are also workshops or application classes for each subject. For 7th grade science class, the students can participate in an application course which is planned and designed by the other science teacher. In this course, the students can obtain theoretical knowledge and practice into related topics.
>
> ... In order to enhance the students' technological ability in education, tablet computers are used by each student in the science class. The students generally use tablets to play games but I encourage the students to use their tablets for educational purposes (card-sorting activity, teacher goals).

Development of communication and interaction among the students was also important for the teacher. Some students had a lack of this skill; therefore, the teacher assigned research topics to such students. Then, the students were asked to present their findings to classmates so as to enhance their communication skills.

Table 4.2. Findings of the Card-Sorting Activities

Topics	Scenarios: parallel	Scenarios: not parallel	Scenarios: not sure
Curriculum and school goals	C2, C3, C5	C4	C1, C6
Work and energy	1, 4, 5, 6, 8	2, 3	7, 9
Simple machines	1, 3, 4, 5, 6, 8, 9	2	7
Friction force	1, 3, 4, 5, 6, 8	2	7

C1: reality of Turkish education system, C2 and C3: gifted education goals, C4: history of development of concepts, C5: affective domain, and C6: science technology sociality and environment goals

Scenarios for topics, 1: process, 2: didactic, 3: academic rigor, 4: conceptual change, 5: activity-driven, 6: discovery, 7: project-based science, 8: Inquiry, 9: guided inquiry.

The teacher was unsure about scenarios C1, C6 regarding whether she could reflect them in her teaching or not. According to scenario C1, taking a high grade from high school entrance exam (TEOG) was important for the teacher but it was not expected from all students to succeed with a high grade because there could be some students having art, music, etc skills and talent instead of academic skills. Thus, the teacher had some doubts about this scenario. Scenario C6, on the other hand, is related to meeting or interviewing the experts to understand effect of technological development on environment and society. The teacher had a positive attitude toward C6 scenario but she did not actually plan any such meeting while teaching the topics, because she did not have enough time to teach the related unit.

The teacher did not select the scenario C4 as a parallel application. She did not explain the historical development of the concepts and she explained the reason as follows;

> …if a student has an interest in the related concept, he/she does research related to the concept. Then, he/she presents it in the classroom. If he/she has a difficulty regarding the research, he/she can ask me, and I explain…otherwise the students get bored when I present the historical development of all the concepts.

Table 4.2 shows the results of the card-sorting activities which were conducted separately for each topic, work and energy, simple machines, and friction force. The first topic analyzed to determine the teacher STO was work and energy, and the scenarios of 1, 4, 5, 6, and 8 were grouped by the teacher as parallel scenarios with her teaching. The teacher selected Scenario 1 as an appropriate activity for gifted students due to the fact that Scenario 1 includes a skill in which students can collect the data by using observation. However, I observed that only two class times were allocated to enable students to engage in lab activities through experiencing of observation, measurement, and discussion skills in the teaching of lever and friction force topics. On the other hand, it was not seen any pedagogical activities related to science process skills during the class observations on teaching work and energy topic. In addition to those mentioned above, while teaching kinetic and potential energy, the teacher tried to engage the students in the lab activities including science process skills. However, the students could not complete the activity due to lack of enough time. Another scenario selected by the teacher as parallel with her teaching was Scenario 4, which includes conceptual change activity in which it aims to determine and handle students' alternative concepts. According to the class observations and post-interview about work and energy, the teacher believed that she used a conceptual change method namely the questioning technique to determine the students' alternative concepts, and the lecturing technique to handle the students' alternative concepts while teaching each topic (Table 4.1). Another scenario parallel with her teaching was Scenario 5, which includes using of models, examples, visual materials, and activities to engage the students in lessons. According to Table 4.1, the teacher used mathematical formula, examples, and visual materials to make the concepts more concrete while teaching work and energy topics. In this regard, her teaching of work and energy topics was in harmony with the feature of Scenario 5. The result of the scenario 6 was related to lab activities which aim to allow students to discover potential and kinetic energy. The teacher selected the scenario as a parallel to her teaching because she integrated a lab activity in her CoRe plan. However, she could not apply any lab activity owing to limited time. The gifted student elaborated the previous topic of work and energy with their questions, so the teacher could not complete her teaching plan on time. Although there was limited time, she had intended to devote the next topics and she tried to engage the students in lab activities for discovering potential and kinetic energy. However, the students could not complete the activity. The last scenario selected by the teacher as parallel with her teaching was Scenario 8, which allows students to participate in an inquiry application. The teacher targeted to exploit an activity to help students to discover the concept of physical work. However, I did not observe any inquiry application for work and energy topics during the class time. Actually, Scenario 8 attracted the teacher's attention very much. The following text reflects her excitement about the scenario;

> …we would like to offer a question or problem to the students to hypothesize related phenomena, to observe, and to conduct an experiment to obtain data. This scenario is like learning science based on argumentation. I would like to apply it through teaching of all units of force and motion (card-sorting activity, work and energy).

As for the scenarios not parallel with her teaching, the teacher selected Scenarios 2 and 3, which are related to didactic and academic rigor activities respectively. The teacher did not prefer to use these activities because she believed that the gifted students would get bored of them. On the other hand, she selected Scenarios 7 and 9, which are related to project based learning and guided inquiry as not sure to apply. Regarding Scenario 7 the teacher explained her reason for not appropriate for her teaching as follows;

> … the students must be voluntary in project works. If a student did not like the topic of work and energy, she/he would be unsuccessful. Students can participate in projects that interest them…

Therefore, the teacher did not have a plan to assign a project topic. If a student was interested in this topic, she would assign the project. The teacher's opinion about scenario 9 is that she refused teacher's help during inquiry application owing to her belief that the students should discover related phenomena in group work.

As for the teacher' STO for topic of simple machines and friction force, similar results to the topic of work and energy were obtained from the card-sorting activities. The teacher selected the scenarios including student-center activities because her aim in teaching of the topics was to encourage the students to become active participant. In addition, she refused to select didactic STO and she was not sure to use the project base strategy in teaching those topics. However, she added Scenario 3 (academic rigor) selected in a group where scenarios were not parallel her teaching for card-sorting activity of work and energy to group where scenarios were parallel her teaching. Furthermore, the teacher believed that the academic rigor includes difficult problems and challenge applications and Scenario 3 was more appropriate for gifted students to elaborate their understanding of the topics. Especially, the teacher thought that simple machines problems and challenged examples help to enhance the students' problem solving and critical thinking ability.

As a result, the participant's STO was investigated in two sections such as the teacher's goals and purposes of science teaching, and science teaching and learning. In addition to science curriculum goals and purposes, her goals of science teaching to gifted students were to enhance her students' knowledge and abilities through providing enrichment activities in order for students to perform their future projects. For this reason, she believed that science process skills required to be performed by students as much as possible. However, she did not have any goals and purposes to integrate nature of science abilities in her teaching. On the other hand, the teacher's belief on science teaching and learning was represented by scenarios including students-centered activities and practices and she refused the teacher-centered application. In other words, she selected the scenarios of academic rigor and didactic as non-parallel teaching activities with her teaching for work and energy. However, she thought that only academic rigor could be employed in enriched activities during teaching of simple machines and friction force. In other words, she believed that her gifted students need to engage in difficult and challenge situations so that academic rigor could provide to meet their needs.

The teacher considered the scenarios of 1, 4, 5, 6, 8, and 9 as representing her teaching because the scenarios have student-center learning activities. Only scenarios 4 conceptual change and scenarios 5 activity-driven were employed by the teacher while teaching three topics. However, there were some mismatches between the teacher beliefs and her applications in the classroom in terms of scenarios 1, 6, 8, and 9. Scenario 1 including science process abilities and scenario 6 including discovery learning activity were applied in a lab activity while teaching both simple machines and friction force but it was not able to apply during teaching of work and energy because of external factors such as lack enough of time, and insufficient inquiry abilities on the students. In this respect, the teacher' beliefs partially aligned with her teaching practices. However, both inquiry learning (scenario 8) and guided inquiry (scenario 9) were not taken place in her teaching practices. In this situation, there was a mismatch between the teacher beliefs and practices.

The teacher was against teacher-centered teaching and her students seemed to be bored of these kinds of applications. However, according to the table 4.1, she generally employed the lecturing technique to introduce new science concepts. She also enriched her lectures by utilizing power point presentation, demonstrations, models, examples and questions in order for students to be active participants.

4.2.2 Knowledge of the Curriculum (KoC)

Science curriculum includes science course objectives, classroom and outside activities, limitations, students' alternative conceptions, timeline (schedule), teaching methods and strategies, and assessment techniques. In this study, the teacher followed the science curriculum to select objectives, materials, and activities to provide conceptual understanding and science process skills. It was seen that the teacher followed the curriculum when she prepared her lesson plans for simple machines including levers, pulleys, inclined plane, and gears and hoops examples by giving equal class hours suggested in the curriculum. However, the teacher arranged the schedule differently from curriculum by allocating 3.5 class hours for levers, 4 for pulleys, 1.5 for inclined plane, and 1 for gears and hoops. She explained the reason for selecting this time order as follows;

> ... Since the science curriculum offers the topics in this order. The topic of levers and pulleys are more emphasized than others and their objectives are more than others. We also did some experiments in the topic of levers and pulleys. Thus they took longer time. The other topics are not as important in the TEOG (entrance exam for high schools) and other exams as the topic of levers and pulleys...(post-interview in the simple machines).

Therefore, the curriculum helps the teacher as a guide because the first aim of her was to achieve the students' conceptual understanding. The other her aim was to enhance the gifted students' abilities by using enriched activities. The gifted students need to engage in different activities since they learned the curriculum objectives and topics easily and in a short time. The exam conducted at the end of the unit was evidence for the students' high scores. The average of the exam was 85 out of hundred.

4.2.2.1 Knowledge of the Enrichment Curriculum (KoEc)

The students showed high performance to understand related science concepts and they could reach curriculum objectives in a shorter class time than that offered by the curriculum for regular students. In the rest of the class time, the teacher arranged or planned different activities to meet the needs of the gifted students. Therefore, I coded these activities in a category called knowledge of enrichment curriculum. According to the data set, different from 7th grade science curriculum the teacher used enrichment curriculum which provides the gifted students with higher or deeper knowledge and applications. The teacher considered the enrichment curriculum as follows;

> ...I use the limitations in the science curriculum as enrichment activities. I am looking for, if there is a limitation for 7th grade students, and if the limitation is appropriate for the students, I can design the limitation as enrichment activity (pre-interview of work and energy).
> ...in this semester, I did not have enough class time and I only planned to apply the problems including mathematical calculation and formula about work and energy. If I have more class time, I will engage the students in high school curriculum objectives. (post-interview work and energy).

The enrichment applications may include integration of upper grades level science concepts and materials into 7th grade level. Table 4.3 shows the teacher's KoC and KoEc in detail in terms of the three topics.

As for analyzing work and energy topics in terms of the teacher’s curriculum knowledge, Table 4.3 shows the differences between KoC and KoEc. The teacher used the knowledge including 7th grade objectives, activities and materials shaping the teacher' KoC. In this category, the teacher's aim was to teach students conceptual understanding of objectives related to work and energy topics. On the other hand, in KoEc category, the teacher used upper grade science concepts, examples, and materials such as a piece of work acted by resultant force, and using a formula to calculate a work done by any objects. For example, while explaining the work done by resultant force, the teacher said that an object having the perpendicular force did not mean doing any work. And then, one student asked; if I applied the force with a 45-degree angle to the pencil, what would happen? Would the pencil do any work? The teacher answered this question by explaining that the pencil was exposed via horizontal and vertical forces, and each force allowed the pencil to travel both vertical and horizontal directions. In doing so, each force and displace provided the pencil with a piece of work. In order to make her explanation more concrete, she gave an example in which a child ascend stairs with a bag in his hand.

The other example of KoEc application in work and energy topics is the questions in Figure 4.1. With the questions, the teacher asked her students to calculate the work of each object by using the following formula;

$$\text{Work (W)} = \text{Force (F)}. \text{Length (X)}$$

As for analyzing the topics of kinetic and potential energy in terms of the teacher’s enrichment curriculum knowledge, the teacher used her KoEc, similar to the one observed in the topics of work and energy. Table 4.3 also shows clearly her KoC and KoEc. The teacher presented the curriculum objectives in the first part of her lesson. In the second part of the lesson, in order to extend their conceptual understanding, she provided the students with enrichment activities requiring her students to use mathematical calculations and formula including units and symbols of kinetic and potential energy. The detail information about the activities was presented under the title of Knowledge of Instructional Strategies.

Table 4.3. The Differences between KoC and KoEc

Topics	KoC (curriculum objectives)	KoEc
Work and energy	To investigate the relationship between force, work and energy. To define work and to specify units of work. To express that the force which acts perpendicular to an object does not mean a work. To identify that energy is the ability of work.	To investigate work done by the resultant force (the effects of sinα and cosα values). To use a formula to calculate the amount of work.
Kinetic and potential energy	To recognize that moving objects have kinetic energy. To discover relationship between kinetic energy and speed/mass. To indicate objects have gravitational potential energy according to their location. To discover relationship between potential energy and height/mass.	To use the formulas to calculate kinetic and potential energy. To specify the units and to identify symbols of the kinetic and potential energy.
Simple machines	To determine how changes the direction of the force. To identify simple machines. To recognize getting greater output force than input force by using simple machines. To identify that simple machines provide only ease of doing work, and not energy savings.	To identify hoists, spinning wheel, gears and hoop as example of simple machines. To consider pulley weight while calculating force. To calculate force and load by using a formula.
Friction force	To show the heat of the friction surface. To recognize that friction force leads to decrease in the kinetic energy. To explain energy transformation in terms of kinetic energy.	To show what factors affect friction force by doing an experiment?

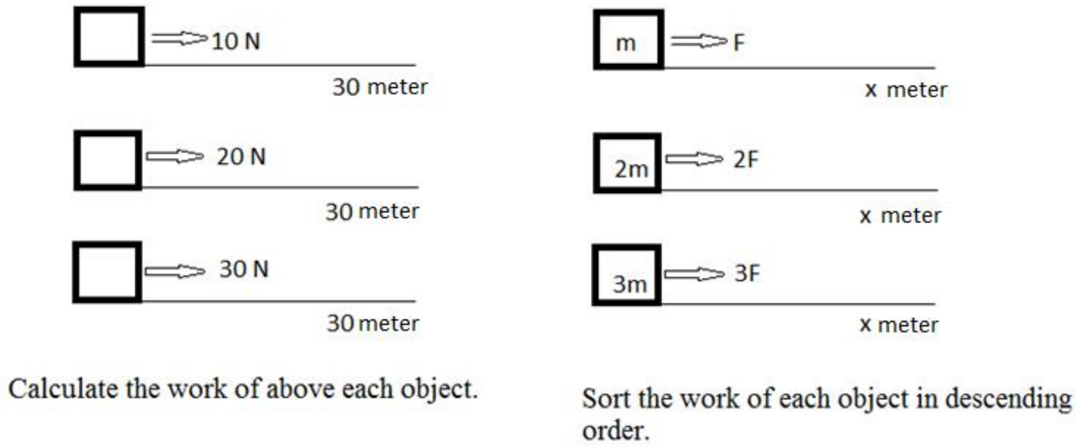


Figure 4.1. Enrichment Activities for Work and Energy

As for analyzing the topics of simple machines in terms of the teacher's enrichment curriculum knowledge, the teacher's ability to design and apply that knowledge was seen more clearly. The objectives in the science curriculum were related to definition of simple machines, examples of them, and their usage areas in daily life. In this regard, the students could attain easily the objectives because of their gifted characteristics, and the teacher offered more complex examples of simple machines such as hoists, spinning wheel, gears, and hoop. Moreover, in order to enhance conceptual understanding of mechanical advantages of any applied force, the formula of each example of simple machine was practiced by the students. After teaching the topics of simple machines, the teacher evaluated her teaching as follows;

> …the elementary science curriculum does not consider hoists in detail but we did. Mathematical formulas and difficult problems were practiced by the students. We will add these applications next year as enrichment activities. These applications are appropriate for the gifted students, and the students had favorable reaction to the applications and problems...
> I will add something about inclined plane. The more difficult questions about inclined plane may be presented. (post-interview of simple machines).

In addition to above activities, combined machines requiring at least three simple machines working together were also introduced by using visual and lab materials, and problems including mathematical formulas were practiced by the students. All these applications mentioned above except for 7th grade objectives were called enrichment curriculum activities and materials.

As for analyzing the topics of friction force in terms of the teacher's enrichment curriculum knowledge, the teacher considered to teach the objectives in one class hour, and in another class hour, the students engaged in lab experiment about investigating the relationships between friction force and surface/weight of objects. This experiment was not addressed in the 7th grade curriculum as an objective, so the teacher considered the experiment as an enrichment activity. On the other hand, the teacher planned to watch a video related to air resistance of the friction force as an enriched activity in order to create the discussion environment with the students. However, having a short time for friction force topic hindered the application of this activity because the discussion requires an extra class-hour.

As a result, the activities including upper grade level objectives and materials except for seventh grade curriculum were designed and practiced by the teacher as enrichment activities. I categorized these teachers' knowledge and abilities as the teacher KoEc.

4.2.2.2 Knowledge of Goals and Objectives and Specific Curricular Program

According to Magnusson et al. (1999), the KoC involves two titles; knowledge of goals and objectives, and specific curricular program. The results of the first title are related to teacher knowledge about concepts in the horizontal and vertical relationship. Horizontal relationship of concepts is that teaching and learning one concept is affected by the teaching and learning prior concept in the same grade level. In doing so, teaching and learning the next concepts are influenced naturally. In this regard, the teacher was aware of effect of horizontal relationship of concepts and stated this relationship as follows;

> … Without teaching the work concept, the students would not understand the concept of energy very well. The energy is the ability of work. It is also important to learn these concepts in the following order; force, work, energy, kinetic energy, and potential energy. The curriculum offers these topics in this order (post-interview about topic of work and energy).

It was mentioned that the teacher followed strictly the science curriculum to select goals and objectives of work and energy topic. Similarly, she considered the simple machines topic in the curriculum order. First, she taught what the simple machines are and then examples of each machine. However, she differentiated the teaching order of the examples of simple machines in the following order; lever, pulleys, hoists, inclined plane, spinning wheel, gears and hoops. Furthermore, she explained the reason of designing this order that an easy way of teaching mechanical advantage and disadvantage is to introduce the example of lever because the other examples of simple machines are more complex than lever. Then, pulley is prerequisite of understanding hoists. Moreover, the teacher used the analogy of lever to teach inclined plane and spinning wheel. In doing so, she believed that her students could transfer the lever knowledge to the application of inclined plane and spinning wheel.

When it comes to analyzing vertical relation of concepts, the teacher’s knowledge was more prominent. The science curriculum was a holistic in terms of the distribution of topics in the grade levels. For example, force concept was considered in each grade level from fourth to eighth in terms of different scientific phenomena and the force concept at each grade must be captured by students so that meaningful learning has been achieved. In this respect, the teacher was able to analyze the science curriculum in terms of the students' prior knowledge. For example, the students engaged in the work and energy, kinetic and potential energy, and simple machines for the first time. However, the friction force has been introduced to the students in the 5th grade, and the teacher designed the lesson based on the students' prior knowledge so in her plan she added an enrichment activity including lab application to discover relationships between surface and mass of objects. On the other hand, when teaching the topics was introduced for the first time, the teacher considered the students' alternative conceptions in the related concepts, and then constructed the target concepts in a meaningful way.

An example of the teacher’s knowledge of the vertical relation of concepts was observed while teaching the energy conservation topic. After the students gained the problems of potential and kinetic energy, the teacher offered the following question (in Figure 4.2) to her students.

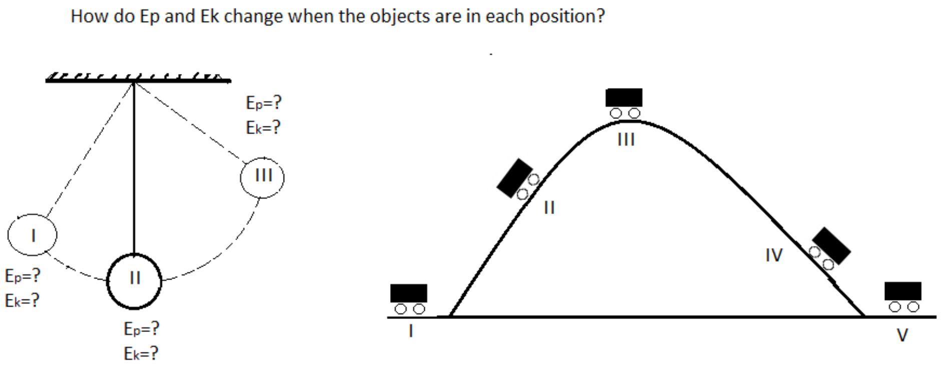


Figure 4.2. Questions about the Energy Conservation Topic

The teacher asked the above question before dealing with the topic of energy conservation. Many of the students could explain the energy transformation from kinetic energy to potential energy and vice versa. I asked the teacher how the students were able to explain energy conservation easily. Her answer is as follows;

> …They have not seen this kind of question before and they don't have knowledge about energy conservation. This topic does not take place in the curriculum before 7th grade. The students have known about topics of force, balanced force, friction force and speed in the 5th and 6th grades. The students were only able to transfer friction force, kinetic and potential energy to energy conservation (post-interview about topic of work and energy).

With this answer, we can say that the teacher effectively used her curriculum knowledge about vertical relation of force and movement units during 4th, 5th, 6th, and 7th grade levels. Moreover, the teacher could assess the students' prior knowledge about simple machines. While conducting pre-interview about teaching simple machine with her, I asked whether the students could understand the concept of lever easily. She explained that;

> …We had difficulty in teaching these concepts in the previous year. I still have difficulty to teach them now because the students don't have any knowledge about simple machines. They know only force, its units and net force from 6th grade but they have never faced levers until now… the students learned friction force in the 5th grade, and they were knowledgeable

> about daily life examples of friction force (pre-interview about topic of simple machines).

The teacher could analyze science concepts in terms of previous and next grade levels effectively. She used the knowledge of vertical relation of the concepts while designing enrichment activities. An example of vertical relation was observed in her teaching kinetic energy. The teacher planned to teach the formula of the kinetic energy and she was concerned whether or not speed and velocity might hinder practice of the formula as speed and velocity are different concepts. Middle school students know the concepts of speed as a covering distance in a unit of time. On the other hand, velocity is a vector quantity and it is in the secondary physics curriculum. The students may have the probable confusion as a result of the enriched activity related to upper grade concepts or practice, and the teacher was aware of this confusion.

Another example of vertical relation of concept in the enriched activities arose from simple machines. The teacher designed enriched activities using the limitation of 7th grade curriculum, namely upper grade concepts and applications such as hoists, gears, hoop, spinning wheel, and problems including practice of the formula of each simple machine. These enriched activities are generally introduced to non-gifted students in the secondary physics classes. However, the teacher thought that it was appropriate to teach these activities to her gifted students, and she commented as follows;

> ... Science curriculum does not contain hoists, gears, hoop, spinning wheel, and mathematical formula of each simple machine. There are limitations for 7th grade students but I will teach all of them. I will offer many problems in class, and provide them more examples in their assignment handouts. I will present numerical tasks which help the students prepare for the high school physics. The students don't have any problems in practice (pre-interview about topic of simple machines).

The final vertical relation was between science concepts and mathematics classes. The teacher planned to practice mathematical formulas of each science topic such as work and energy, and simple machines. However, the students' problem solving abilities should be improved enough to practice enriched activities as some formulas include complex equation solving and each formula requires specific mathematical abilities. The teacher had some previous experiences related to this issue, and predicted some difficulties. Therefore, she communicated to the students' math teacher to obtain some information about their problem and equation solving abilities. For example, the equation of kinetic energy requires abilities of

$$K_E = \frac{1}{2}. m. v^2$$

cross-multiplication and exponential numbers, and the students had these abilities. However, calculation work of an object including net force with an angle requires background knowledge in trigonometry such as the formula;

$$W = F. \sin\alpha . X$$

Therefore, the teacher avoided explaining this equation while the students were calculating any object work because she knew that the students would learn trigonometry in the 8th grade level. As a result, it is evident from previous case, the students' limited abilities or background knowledge may affect the teacher's presentation of enrichment activities.

The results of the second title offered by Magnusson et al. (1999) are related to knowledge of specific curricular programs, which refer to substantial curriculum development. The science curriculum has been reviewed a few times since 2006. According to the latest update of science curriculum in 2013, the simple machines topic was moved from 7th grade to 8th grade but the objectives and limitations of the topic were not changed. In this respect, the teacher was aware of this change and she expressed it as follows;

> If the students' math background were slightly better, understanding of simple machines would be easy for the students, and I could have offered more difficult questions. Fortunately, according to the new science curriculum, the simple machines will be taught at 8th grade. In the 7th grade, teachers had difficulties to teach simple machines for both non-gifted and gifted students owing to fact that the topic requires more complex abilities such as scientific reasoning and math abilities (post-interview about topic of simple machines).

The teacher has followed the specific updated curriculum which might affect her teaching. She thought that this change was appropriate for all students in 8th grade because they would have acquired mathematical calculation abilities helping better understand the simple machines.

Overall, MNE has offered the curricula including abundant contents, materials, activities, etc., and the curricula have served as a guide for teachers to design and practice their teaching. In this respect, the participant teacher had sound knowledge about applications of both middle school and high school curriculum on her teaching in terms of the topics of work and energy, simple machines, and friction force. Moreover, vertical and horizontal relationships of science concepts are substantial for meaningful learning, and the teacher could link students' prior knowledge to new concepts. In doing so, the relationships help successfully design and practice enrichment activities requiring detailed knowledge and difficult problems for gifted 7th grade students. Furthermore, the teacher was aware of particular program changes for that reason she believed that it is necessary to follow science curriculum strictly.

4.2.3 Knowledge of Learner (KoL)

Another PCK component is knowledge of students' understanding of science which was categorized in four subtitles in this study; (1) knowledge of the characteristics of gifted students, (2) knowledge of requirements for learning, (3) knowledge of areas of student's difficulty, and (4) knowledge of areas of student's alternative conceptions.

4.2.3.1 Knowledge of Characteristics of Gifted Students

Some students' behaviors were taken attention during class observations, and I discussed them with the teacher in the post interviews. The teacher explained some of the students' behaviors that must be in the gifted students, such as quick and easy learning related to science concepts, asking difficult and interesting questions, and extending enriched activities and discussions. I coded these examples of the behaviors as a teacher's knowledge of characteristics of the gifted students because these behaviors affected the teachers' both planning and teaching any science topic. The detailed information about knowledge of characteristics of the gifted students was illustrated in Table 4.4.

Table 4.4. Characteristics of the Gifted Students

Topic	Code of the behavior	Example or result of the behavior
Work and energy	Students are not easily persuaded	They did not easily accept the work concept explained by the teacher.
	Students love to discuss with teacher and friends.	The discussion leads to waste of class time.
	Students ask difficult and interesting questions	What happens if I move the pen at an angle of 45 degrees? Because of moving electrons in any stable object, does it not have kinetic energy?
	Students have impossible aims	They tried to conduct experiments impossible to be done in the classroom.
	Students can extend the enriched activities.	The teacher had to explain work arising from resultant force
Simple machines	Students can extend the enriched activities.	They asked whether the angle affects the force in the inclined plane or not. They discovered the weight of pulleys had an effect on input force.
	Students are not easily persuaded	They asked why the fixed pulley does not have mechanical advantages. They did not easily accept movable pulley having mechanical advantages. They did not easily consider simple machines as tools in daily life instead of technological tools.
Friction force	Students can learn quickly and easily	They learned the friction force and conducted experiment in two class hours.

The teacher said that her students interrogated nearly all science concepts and they were not easily persuaded to learn new information. An example of this situation is that, while teaching work concept, the teacher had difficulty in explaining differences between the physical work and the work done in daily life, and she was subjected to many questions coming from the students defending their arguments. These questions were regarded by the teacher as sometimes difficult and sometimes interesting. The questions also led the teacher to explain more information related to upper grade concepts. For example, the students could work out the logic of resultant force with angle of 45 degrees on any work, and the teacher had to explain the work done by vertical and horizontal forces, which are related to high school physics topic. The students also extended the discussion, so the teacher could not cover the lesson topic on time and had to use next lesson to complete the objectives. While conducting post-interview about work and energy topic, I asked the teacher what the possible sources of these kinds of questions asked by the students were. The teacher explained this as follows;

> … The students know many things because they search and read… we also give TÜBİTAK books in the beginning of semester. The books include high school and university level topics. When the students read them, they challenge my lesson and they ask interesting and difficult questions. I am sure that they are more knowledgeable about simple machines because the topic takes place in the chapter of TÜBİTAK book.

One characteristic of the gifted students was to extend the enriched activities by their questions. Although the teacher generally planned enriched activities for her students by designing upper classes concepts and materials such as giving formula of work and providing the students to practice problems related to work topic, the students realized some concepts including limitations of 7th grade science concepts such as reluctant force with angle in the work, energy and inclined plane, weight of the pulleys in the simple machines, movement of the electron in the kinetic energy. These limitations would not be mentioned in her lesson planes because the students did not have enough prior knowledge and abilities to understand these limitations. However, the students could discover these limitations by their questions and the teacher had to include these in her teaching practices.

Another characteristic of the gifted students is that the students did not accept the teacher explanations and they needed to see more concrete examples and explanations. For example, while the teacher introduced the fixed pulley as not having any mechanical advantages, other than changing the direction of a force, a student immediately objected this by drawing attention to general definition of simple machines;

> Student: Why do we use this (fixed pulley) as a simple machine? It does not fall into definition of the simple machines.
>
> Teacher: Yes, it does not have mechanical advantages but it enables us to change the direction of a force. So we can say that it is a simple machine (class observation of simple machines).

In this example, the student compared the definition of simple machine in the example of levers, which was taught by the teacher two weeks ago, with a new example of simple machine's fixed pulleys. Therefore, the students generally did not accept the teacher explanation as a correct knowledge. Moreover, this characteristic of gifted students appeared during the teaching of movable pulleys. While the teacher was explaining mechanical advantage in the moveable pulley, a student did not understand and he did not accept the teacher's explanation. He asked the teacher to explain this in a more concrete way persistently. Then the teacher had to use three different teaching techniques, which were explained in detail in the knowledge of instructional strategies title.

Another characteristic of the gifted students is learning any topic in the 7^{th} grade curriculum quickly and easily. The objectives of friction force were learned by the students in a class hour. In other words, the teacher could finish teaching all objectives in an hour. During the second class hour, the students engaged in an experiment to discover the relationships between friction force and surface/weight. The students' exam results (average score is 85 out of 100) are the evidence that the student understood friction force in a class hour easily and quickly.

As a result, the teacher considered the characteristics of the gifted students shown in Table 4.4 when planning and teaching related topics owing to fact that the students' knowledge and characteristics affected her teaching. During both interviews and observations, the teacher explained the above examples of gifted students' behaviors in the class as students' general characteristics. Thus, I coded each of the students' behavior as teacher knowledge of characteristics of gifted students.

4.2.3.2 Knowledge of Requirements for Learning

The science curriculum has a holistic structure including science concepts connecting with upper or lower class concepts. In order to achieve meaningful understanding related to science concepts, students need to know prerequisite concepts. In this regard, the teacher was knowledgeable about students' requirements thanks to her knowledge of curriculum. She could assess each of her students in terms of their requirements for learning. The teacher stated prerequisite concepts in the CoRe plans and interviews for each topic shown in Table 4.5.

Table 4.5. Prerequisite Concepts for Teaching Related Topics

Topic	Prerequisite concepts
Work and energy	force, net force, reluctant force, work (to understand kinetic and potential energy), friction force (to understand conservation of energy)
Simple machines	work, energy, lever (to understand spinning wheel),
Friction force	friction force in the daily life examples, simple machines

While conducting the observations, I realized some concepts or skills necessary for the students to understand related concepts. For example, differences between mass and gravity hindered the teacher's teaching of potential energy. Some students did not remember the differences between mass and gravity taught in the 6^{th} grade. Another example was observed in the enriched activity. While learning the topic of levers in laboratory work, the students did not have enough knowledge about the unit of force and gravity. However, the teacher did not mention the differences between force and gravity as a pre-requisite knowledge in her core plan. The units were also taught in the 6^{th} grade.

In addition to pre-requisite knowledge, there were some skills necessary for conducting the activities such as using dynamometer, and making mathematical calculations. The first one was not stated by the teacher in her CoRe plan, it occurred during laboratory work by measuring the force. Some students were not able to use the dynamometer in the experiment and the teacher had to explain its usage. The second one related to making mathematical calculations was a concern for the teacher during enriched activities owing to fact that the teacher designed the activities including formula necessary for students to have mathematical calculation skills. In this respect, each formula requires using equation solving ability but some students did not have them. Some formula also includes exponential numbers, which led to confusion in students' minds. Moreover, some students were not able to calculate equations with units of each variable (e.g., W=10N×30 meter). As a result, the lack of enough students' mathematical ability was a difficulty for the teacher and she expressed this difficulty in her CoRe plans. However, the other three examples mentioned above were not stated by the teacher in her CoRe plan as students' prerequisite knowledge to understand related topics.

In this part, the students' learning styles may be necessary as a part of prerequisite knowledge for the teacher. The teacher could evaluate students' learning during her classes because her class has 12 gifted students. Each student has a different learning style and the teacher was aware of this difference. For example, two students enjoyed inquiry and read immensely from different sources. Thus, the teacher had to design enriched and interesting activities to meet their needs. On the other hand, another two students have memorizing learning style and they enjoyed repetition about related topics. In order to ensure their learning, the teacher generally summarized the learning at the end of each concept and she had the students take note about the related topics. Furthermore, the eight students enjoyed engaging in student-centered and hands on activities.

4.2.3.3 Knowledge of Areas of Student Difficulty

This part involves the teacher knowledge about the students' difficulties hindering students' understanding of related topics. According to the teacher, the students considered the unit of force and motion in each grade level 6^{th}, 7^{th}, and 8^{th} as a difficult unit for understanding of related to science concepts. In other words, the students were biased against the physics topics because the science concepts of work and energy, simple machines and friction force are abstract topics.

The students had difficulties in learning the topics of work and energy, and simple machines. Some students did not understand the teacher's explanation, and the teacher stated this situation as follows;

> ...When I used verbal explanation, a few students had difficulty in understanding. The student asked me to make more concrete explanation. When I explained the mechanical advantages by using examples including mathematical calculation, I observed that students had a better understanding (post-interview about topic of simple machines).

... I understood from examples including mathematical calculation that the students wanted to see something more concrete just like numerical evidence. After I gave the mathematical problems, the students understood. The curriculum does not include that problem but I will offer more problems... may be, I could have started by teaching problems first (post-interview about topic of work and energy).

One example of the students' difficulty appeared while teaching spinning wheel. When the teacher drew the shape of spinning wheel (Figure 4.3 part A), and explained the relationship between force and load, one student had a difficulty in understanding the location of the applied force. Then he asked the teacher what would happen if they applied the force in the different location of the spinning wheel (Figure 4.3 part B), and would the force or r_2 change? The teacher gave the answer of student's questions by explaining and drawing a new shape of spinning wheel shown in Figure 4.3-part B.

Another example of the students' difficulty resulted from enriched activities. The unit of force and motion has already been difficult to understand by the students. The teacher offered enriched activities but these activities made the learning of the related concepts more difficult. Figure 4.4 shows two examples of enriched activities including the questions below.

The two questions include upper class concepts and applications such as homogenous bar, weight of pulley, and distribution of the forces into the rope. Each upper concept was asked by the student, and the teacher had difficulties in teaching them.

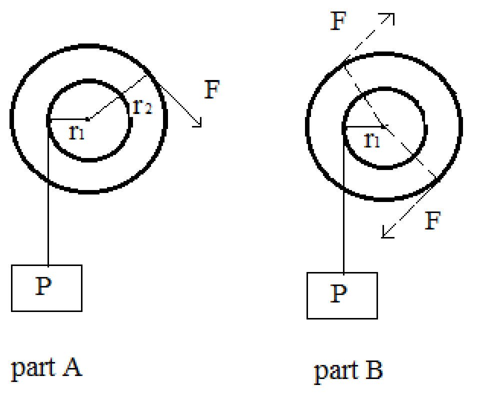


Figure 4.3. Teacher's Explanation of Spinning Wheel

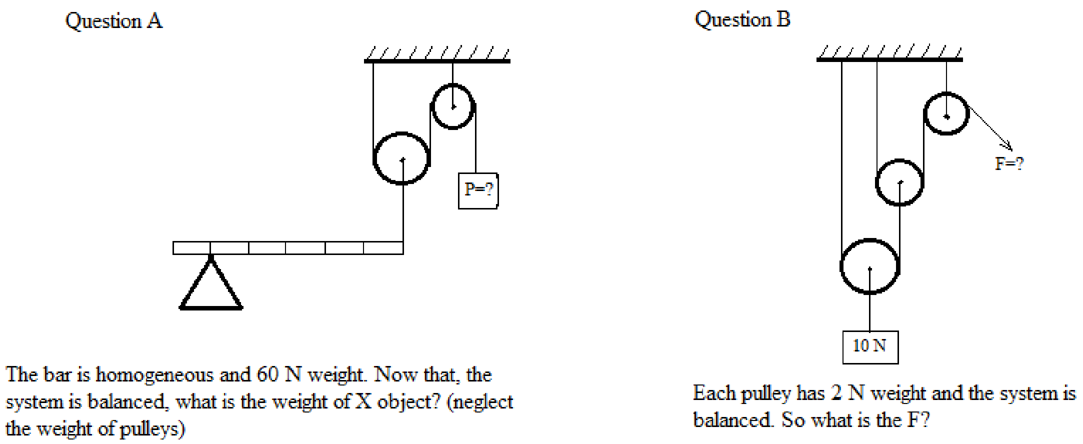


Figure 4.4. Example Questions of Enriched Activities

As a result, the teacher's knowledge of areas of student difficulty was affected by two factors. The first factor was students' prerequisite knowledge, mentioned in the previous part, of unit force and motion including abstract knowledge, and requiring measurement and calculation skills. The lack of students' knowledge and skills led to learning difficulties. Moreover, the unit of force and motion includes abstract concepts and learning this unit is more difficult than other units including chemistry and biology topics. The last factor was enriched activities including applications and examples related to upper class concepts and mathematical calculations designed by the teacher. Each enriched activity caused learning difficulties in related topics.

4.2.3.4 Knowledge of Areas of Student's Alternative Conceptions

The students had some alternative conceptions arising from daily life, their experiences, or reading upper grade resources owing to fact that the topic of work and energy, and simple machines were first introduced in this grade levels. In other words, the students did not have formal experience related to these topics. The students' alternative conceptions about work and energy, simple machines, and friction force were summarized in Table 4.6.

The students thought that work is doing anything which requires energy and some students' alternative conceptions about the work concept were as follows;

S1: people engage in the daily routine for earning money.

S2: work is to make an action.

S3: work is a successful action made by machines

S4: work is an action which we do a certain time and which is continuous.

S5: we do something to support our living.

In order to handle these alternative conceptions about work, the teacher used different teaching techniques, which were explained in the next part. Some alternative conceptions were also observed while teaching of the topics of kinetic and potential energy. The students thought that kinetic and potential energy were affected by only one variable such as mass or high and speed or mass. They also explained that a fast car had more kinetic energy than a slow car, and an object at the higher position had more potential energy than one at the lower. They did not consider mass of the car and the object.

When it comes to analyzing simple machines, some alternative conceptions were detected. The students explained the simple machine as complex machines including electrical devices, wires, and motors. Some students described the simple machine as something used to save energy, and to obtain mechanical advantages from work and energy. Moreover, one student was affected by the teacher's drawing of inclined plane's shape and he understood that objects always were carried by dragging from lower side of inclined plane to upper side. Thus, the student did not accept the stairs as an example of inclined plane.

Finally, one alternative conception about friction force was that friction force is always in the opposite direction to the object's motion. According to Table 4.6, the teacher was not generally aware of the students' alternative conceptions. I coded these as "the teacher is not aware of it". However, there were three alternative students' conceptions which the teacher was aware of them as she had already stated them in her CoRe plans.

Table 4.6. Students' Alternative Conceptions

Topic	Alternative conceptions of students	Awareness of the teacher
Work and energy	Work is anything someone does in daily life.	Yes
	A fast car has more kinetic energy than a slow car.	No
	An object which is at the higher position has more potential energy than the one is at a lower position.	No
	Speed and velocity are the same things.	Yes
	Energy is lost when it changes from kinetic to potential	No
Simple machines	Machine is something which includes technological elements.	Yes
	Stairs are not an inclined plane because we cannot transport any object along the stairs by dragging.	No
	Mass and weight are the same things.	No
	We can obtain mechanical advantages from work and energy.	No
Friction force	Friction force is always in the opposite direction to the object's motion	No

4.2.4 Knowledge of the Instructional Strategies (KoIS)

According to the Magnusson et al. (1999), this component of knowledge of instructional strategies comprises of two subtitles; subject-specific and topic-specific strategies. In this study, the teacher did not practice any subject-specific instructional strategies such as learning cycle, conceptual change, and inquiry. Thus, I did not include the teacher's knowledge of subject-specific instructional strategies in this part.

4.2.4.1 Knowledge of the Topic-Specific Instructional Strategies

The teacher's teaching pattern was shown in Table 4.1 and the teacher generally practiced different topic-specific strategies based on the nature of the topics. I explained the teacher' knowledge of topic-specific instructional strategies under separated titles.

4.2.4.1.1 Topic of Work and Energy

The teacher included argumentation technique in her CoRe plan and stated that she would use it to teach work and energy topic. As for the rational, she explained that this technique was more appropriate for the gifted students and would help the students become more active, motivated in learning the topics. Moreover, the teacher elaborated her opinion about using argumentation as follows;

> …it (argumentation) aims to develop the students' thinking and interpretation skills. It is a process during which the students can first estimate, then, observe, and finally, draw conclusions about scientific phenomena. I will arouse their interest. In this respect, I think it is very appropriate for gifted students who are curious about and keen to do research (CoRe plan for work and energy).

The teacher planned to use the questioning technique enriched with simulations and examples in the daily life to teach work and argumentation technique to teach kinetic and potential energy. She also planned to start the teaching of kinetic and potential energy by using a case, questioning, and examples.

When it comes to analyze the data gathered during observations of teaching work and energy, there were some differences between her plans and practices. The teacher used questioning technique to determine the students' prior knowledge, daily life examples to promote the creation of a discussion friendly environment. Then she explained the work by using power-point presentation and illustrations. However, some students were not satisfied with her explanations and challenged her by giving conflicting examples to better comprehend the work. The students' questions led the teacher to offer enriched activities including visual examples, demonstrations, and mathematical formula. Finally, the students understood the work topic after practicing numerical problems illustrated in Figure 4.1. The teacher expressed her feeling as follows;

> ... I understood from examples including mathematical calculation that the students wanted to see something more concrete just like numerical evidence. After I gave the mathematical problems, the students understood the topic. The curriculum does not include numerical problems but I will offer more problems... maybe, I should have started to teach with problems (post-interview about topic of work and energy).

Before finishing the teaching work and energy, she let the students take notes about work and energy.

Similar teaching pattern appeared in the kinetic and potential energy. The teacher started the lesson with questions in order to determine the student's alternative conceptions and to help them recall previous concepts. Then, she explained the topic by using power-point presentation. After introducing kinetic and potential energy, she asked the students to design a research question as a group and conduct an experiment in order to solve the problem and to reach a result. The teacher called her teaching method as argumentation and mentioned it in her CoRe plan. However, the students did not engage in argumentation due to many reasons such as insufficient time and shortage of materials. The students seemed to not have argumentation skills. Moreover, some students determined inappropriate research questions to collect data in the classroom environment. One example was mentioned as follows;

> T (teacher): …can I ask you what you are wondering?
>
> S (student): of the objects having different mass which one consumes more energy than others?...or … for example, does an airplane consume more kinetic energy than potential energy?... we need an both moving and flying object to test our question… or a balloon…how do we determine the airplane's speed? What is our reference?
>
> T:…you should try something else! …there are those who have not still determined the problem.
>
> S: we lack some materials so are not able to do it.

T: make sure you have requirement material until the next lesson. You will present your experiment… you should first determine a research question in a group, and then test it to find a solution.

The next lesson, the students did not present their experiment owing to fact that they could not find a research question to test. Thus, the teacher had to continue to introduce kinetic and potential energy by lecturing in detail and she explained the formula of these kinds of energies. Then, she asked the students to solve two numerical problems mentioned in Figure 4.5. First, the teacher presented question A, then question B because the students had difficulty in comprehending the relationship between mass and speed in the kinetic energy. The students thought that the higher speed any object had the more kinetic energy it had. They did not consider that mass might affect the object’s kinetic energy. In order to handle this difficulty, Question A required the students to compare the kinetic energy of identical objects in terms of their speed. On the other hand, Question B required the students to make same comparison with objects having different masses to gain more meaningful understanding of the relationship between mass and speed in the kinetic energy. Moreover, the similar difficulty appeared while teaching potential energy. The students had difficulty in understanding the effect of mass and height on potential energy. In order to handle this difficulty, the teacher explained each effect of mass and height by using demonstration.

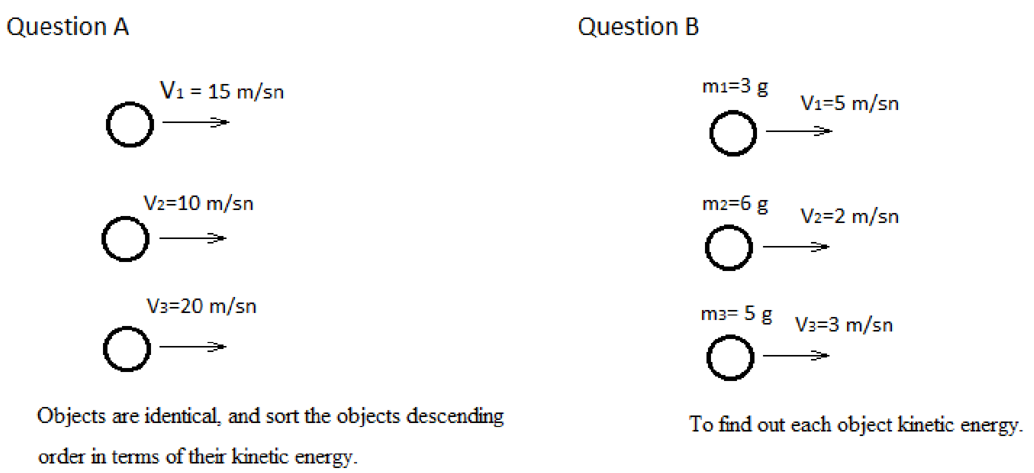


Figure 4.5. Questions of Kinetic Energy

After teaching kinetic and potential energy, the teacher briefly explained the potential energy of spring, and continued with the next topic, the conservation of energy. She wrote the questions in Figure 4.2 and encouraged the students for discussion. The students could transfer the knowledge of kinetic and potential energy into the interpretation of the new topic. The teacher finished her lesson after offering more examples of energy conservation in daily life such as roller coaster, sky diving, and motion of a plane, and the students took notes related to the topics.

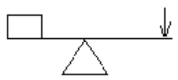
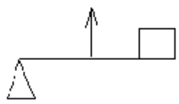
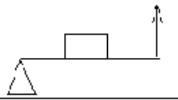
4.2.4.1.2 Topic of Simple Machines

During the pre-interview about the use of instructional strategies in the simple machines, the teacher stated that she would start the lesson by using questioning technique to determine the students' prior knowledge on the related topics. Then, she would explain simple machines with some examples from daily life, and introduce the formula for each example of the simple machines. So far, the teacher planned to use didactic teaching orientation. However, she stated in the interview that she would engage the students in laboratory work while teaching pulley or inclined plane as she felt that laboratory work provides the students with meaningful learning. She also believed that the students could arrange the height of inclined plane by using hands-on activities or materials so that they could better comprehend the relationship between force and load. As a result, it was clear in the teacher CoRe plan that the teacher was keen on using the laboratory work as much as possible.

On the other hand, the observations data were in aligned with the data of her CoRe plan. The teacher's teaching strategies observed during her classes are also shown in Table 4.1. She started to introduce the topic of simple machine with questioning technique in order to determine the students' prior knowledge as she mentioned in her CoRe plan. She also tried to correct the students' alternative conceptions by using lecturing.

The first example of simple machine was the levers. She introduced the lever, positions of the fulcrum, and gave everyday examples of its usage by using questioning technique. Then, she asked the students to group for laboratory work, and she gave them the materials to discover the relationship between force and load in the lever. The students were engaged in laboratory work by using dynamometers, weights, and rulers. As some students had difficulty in using the dynamometer and understanding the activity, the teacher helped them get involved in the activity by explaining prerequisite knowledge and skills. During activity, the students formed their group data, and at the end of the activity, they presented their group results on the board (Figure 4.6 shows two of groups' results) and discussed each result in terms of mechanical advantages. Each group had some incorrect measures resulting from students' carelessness, but the teacher explained their mistakes and corrected them by using demonstration. As a result, the teacher enabled the students to practice inductive laboratory work where the students first discovered the mechanical advantages of simple machine and were given the formula of the lever. Moreover, the shape of the lever helped students understand the mathematical equation of the formula. Namely, the teacher used the analogy between the shape of lever and its mathematical equation.

group A

lever	load	load distance	effort distance	force
	2 N	18 cm	20 cm	2 N
	2 N	38 cm	38 cm	2 N
	2 N	19 cm	38 cm	1 N

group B

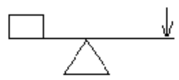
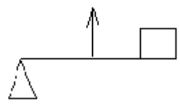
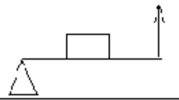
lever	load	load distance	effort distance	force
	2 N	19 cm	19 cm	2 N
	2 N	38 cm	19 cm	2 N
	2 N	19 cm	38 cm	1 N

Figure 4.6. Groups' Results of Inductive Laboratory Work.

The second example of simple machine was pulleys. The teacher started to introduce the topic of pulleys by using questioning technique to determine the students' prior knowledge as she did in previous teachings. After controlling the students' alternative conceptions, she used lecturing to explain pulleys and models including fixed and movable pulleys. She also gave examples from daily life. While explaining movable pulleys, a student did not understand mechanical advantages of the pulley. The teacher first wrote verbal explanation on the board in order to inform the students on mechanical advantage, and then she tried to show with demonstration by using pulleys. However, the student was not satisfied with her explanations. Finally, the teacher had decided that the student should be engaged in practice using pulleys. The student first measured a weight of 200 grams with dynamometer and recorded it. Then, the student measured the same weight in the fixed pulley and the movable pulley respectively as shown in Figure 4.7.

After all measurements were completed, the teacher asked the students to compare the results. Finally, the student noticed that the object in the movable pulley had half of weight of the object in the fixed pulley. As a result, the student's demonstration of the mechanical advantage of pulleys provided more concrete evidence and better understanding.

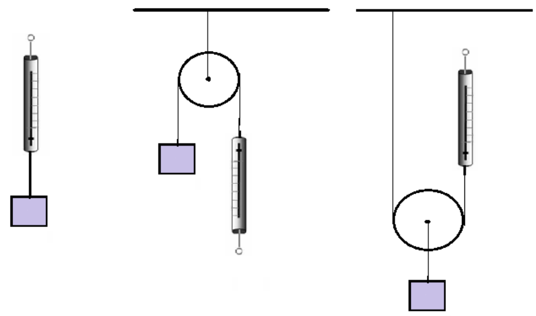


Figure 4.7. The Student's Measuring Process

After understanding of differences between fix and movable pulley, the students took notes. Then, the teacher drew an example on the board shown in Figure 4.8a to provide better understanding of differences between fixed and movable pulleys. After all, the teacher drew Question B on the board to show relationship between force and load in the pulleys. One student solved this question in one minute and only two students did not reach the correct answer. While the teacher was explaining Question B, one student objected to her explanation and he raised a question that “we should have considered the weight of pulleys because the pulley keened to force into downward just like a load”. The student’s question led to the teacher to introduce weight of pulleys which affects mechanical advantage of pulleys. In other words, the student caused the teacher to extend enriched activities. The teacher did not plan to introduce the weight of pulley but she had to explain by using an example shown in Figure 4.8c because of the student’s suggestion.

After analyzing pulleys in terms of the teacher’ knowledge of instructional strategies, the next example of simple machines is hoists. The teacher started to introduce the topic with questions related to usages of hoists in daily life. Then, she explained hoists by drawing their shapes on the board. However, some students did not understand very well and they disagreed with her explanations about the relationships between force and load. Accordingly, the teacher decided to introduce hoists by drawing four questions mentioned in Figure 4.9 and explained step by step. Question A includes a fix pulley and Question B includes both a fix and a movable pulley.

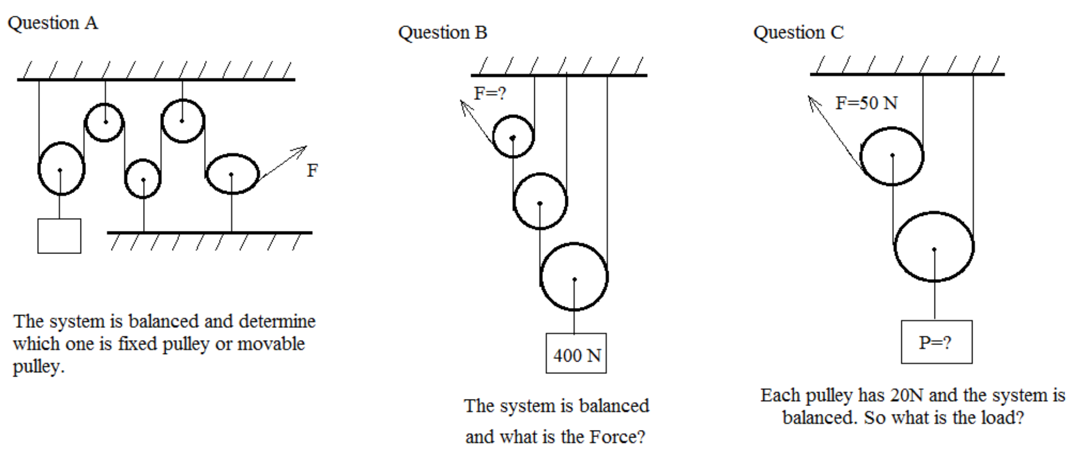


Figure 4.8. Questions about Fix and Movable Pulleys

These questions provide the students with permanent learning about the differences between fix and movable pulleys in terms of mechanical advantages. Question C offers a combination of two movable pulleys and one fix pulley. The teacher, first, explained mechanical advantages of using movable pulleys, which is shown with red circle in Figure 4.9. And then, she explained the relationship between the force and the load on fix pulley. Moreover, Question D provides the students with an example of three movable pulleys and one fix pulley with a similar facilitation as in Question C in order to help them better understand mechanical advantages of a hoist. After solving each question, the teacher allowed the students to take note about hoists. During the post-interview about the simple machine, the teacher explained that these four questions helped the students comprehend the rationale of hoists more easily, and she believed that all the students understood the topic of hoists.

Another example of simple machines was the inclined plane in which the teacher’s knowledge of instructional strategies was observed. The teacher started to introduce the topic with questioning, and the teacher continued lecturing by offering visual materials. In order to explain the relationships between force and load on inclined plane, she used demonstration technique by using lab materials. During the demonstration, some students negotiated the teacher’s explanation as they did in the previous classes, and they discovered the effect of angle on the force in the inclined plane. In the teacher’s CoRe plan, she had not planned to present the effect of angle on the inclined plane, but she had to introduce the angle effect briefly because of the students’ negotiations. After all, the teacher presented the formula and examples of inclined plane.

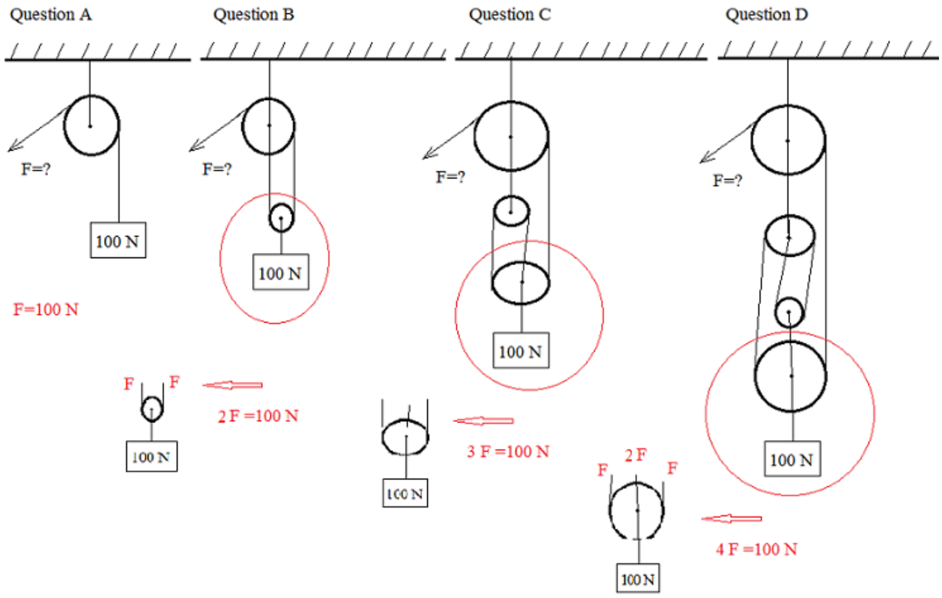


Figure 4.9. Questions about Hoists

The next example of simple machines is the spinning wheel, and the teacher started to introduce the lesson with the summary of levers because she believed that the topic of levers might help students' understanding of the spinning wheel. In order to facilitate the introduction of the spinning wheel, she used visual materials and daily life examples. Then, the teacher drew the shape of the spinning wheel and explained its formula. However, some students did not understand her explanation of the formula, which is used to calculate mechanical advantages of the spinning wheel. Therefore, the teacher decided to use analogy between the spinning wheel and the levers to clarify the formula. Figure 4.10 shows the teacher's drawing of the spinning wheel and the lever. During the post-interview of simple machines, the teacher stated that the analogy helped the students understand the concepts more easily owing to the fact that the students could transfer the knowledge of mechanical advantages from the lever to the spinning wheels. After presenting the analogy, the teacher offered the question as shown in Figure 4.10 to enhance the students' understanding of the spinning wheel.

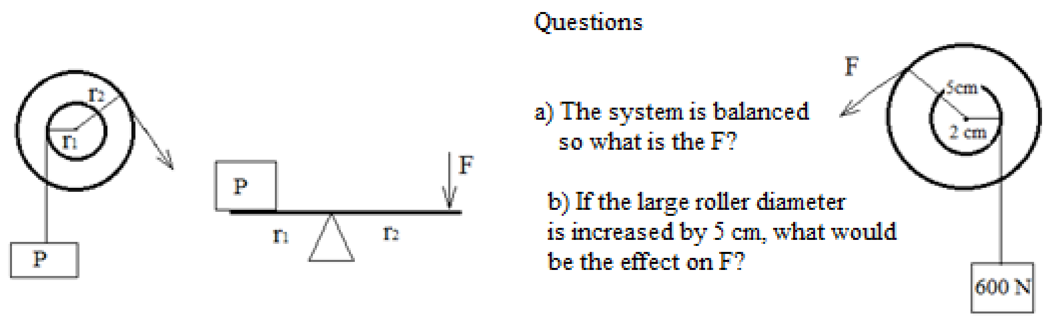


Figure 4.10. Shapes of Lever and Spinning Wheel, and One Question about Spinning Wheel

The last topic of simple machines is the gears and the hoops. The teacher started to introduce the topic by using questioning to activate their previous knowledge as she previously did. She also used a model related to the gears and the hoops to show direction and the number of revolutions of gears. Then, the students work on the model, and she explained formulas of the gears and the hoops. At the end of the class, the students took notes and solved the problems related to the gears and the hoops.

4.2.4.1.3 Topic of Friction Force

The last topic taught by the teacher is friction force. The teacher first determined students' alternative conceptions about friction force by using questioning technique since the topic had first been introduced to students in the 5th grade. After going over the friction force briefly, the teacher decided to engage the students in laboratory work because the students had enough knowledge to understand the relationships between the friction force and the surface/mass of any object. The teacher had planned to start teaching with lab application in her CoRe plan. Thus, she delivered the materials (e.g., dynamometers, weights, sandpapers, wood cubes, etc.) to the students and encouraged them to practice. The students first tried to investigate the relationships between the friction force and the surface, and they used two different surfaces (student desk and sandpaper) with a wood cube. The students measured the weight of the wood cube in three situations, which is shown in Figure 4.11. Then, the students tested two wood cubes having different weight in a stabile surface for the second experiment in order to understand that the weight of a wood cube affects the friction force and there is a direct proportion between the weight and the friction force.

first experiment	weight of the object	surface of desk	surface of sandpaper
force	1.1 N	0.3 N	8 N

second experiment	object I	object II
weight	9 N	10.1 N
force	1.8 N	3.2 N

Figure 4.11. Students' Group Results of Inductive Laboratory Work

During the laboratory work, the students collected their group data, one example of them was shown in Figure 4.11, and they discussed each group's results in terms of friction force/surface and friction force/weight. Although the teacher planned to present the mathematical problems related to friction force in her CoRe plan, she did not present any formula and mathematical problems. She believed that knowledge and skills covered by the students in the laboratory work were enough to introduce friction force for 7th grade students.

4.2.5 Knowledge of the Assessment (KoA)

The teacher could assess each of her students in detail in terms of students' conceptual understanding owing to the fact that the number of students was twelve in her class. In other words, the individual assessment was carried out by the teacher. She also felt that individual learning should be monitored because planning and practicing enrichment activities including difficult and upper class concepts were required to determine the students' pre-conceptions or understanding of related topics. For example, in the laboratory work of the friction force, the teacher had checked all students' previous knowledge and decided that her students had enough knowledge in order to discover the relationships between friction force and surface/mass. Moreover, after introducing the pulley topic, the teacher assessed students’ understanding and reached the conclusion that all students had covered the mechanical advantages of force in the movable pulleys. In doing so, she thought that the students could understand the hoist topics which were enriched activities including three and more movable pulleys and a fix pulley.

All students were successful at the end of the unit exam which was prepared based on the science curriculum objectives and the average of exam results was nearly 85. However, the teacher did not believe that every student would be successful in enriched activities owing to fact that each student had different abilities and interests. For example, the teacher stated in the pre-interview about simple machine that two students might not like the hoists and she would not force them to understand the hoists because their interest areas were different from the general class. Thus, teaching only the topic of pulleys which are in science curriculum was enough for these students to comprehend. In this respect the teacher’s knowledge of assessment was analyzed in two sub-components as mentioned below.

4.2.5.1 Knowledge of Dimensions of Science Learning to Assess

The goal of the teacher for assessment in this study was generally to assess dimension of the students’ conceptual understanding. The teacher’s goal of the assessment comprised of three sub-dimensions; student’s prior knowledge, content assessment, and grading students’ performance. Table 4.7 shows summary of the teacher’s knowledge of assessment.

At the beginning of the lesson, the teacher tried generally to elicit the students’ prior knowledge or alternative conception related to topics. While teaching related topic, the teacher assessed how much the students understood those concepts. This assessment pattern was observed during the teaching of work and energy, simple machines, and friction force topics. The teacher performed diagnostic assessment in the beginning of each topic to elicit prior knowledge and formative assessment during her teaching to monitor how many the students attained the objectives. On the other hand, the teacher only used summative assessment to grade the students' performance at the end of the unit after teaching friction force.

4.2.5.2 Knowledge of Methods of Assessment

The teacher generally assessed the students' conceptual understanding and used informal techniques (questioning and observations) and formal techniques (quizzes, tests, or homework).

While teaching work and energy, the teacher used questioning technique to elicit students' prior knowledge at the beginning of the class. The questions included open-ended questions to encourage the students to discuss. If the teacher realized incorrect or lack of knowledge, she tried to cope with the misunderstanding or complete the inadequate information about related topics by using verbal explanations. After completing the students' prerequisite knowledge, the teacher observed each student to assess learning performance during her teaching. The interaction between the students and the teacher could help her monitor how many the students understood the topic. For example, while performing the problems of kinetic energy, the teacher checked each student's results and gave feedback. At the end of the lesson, the teacher administered quiz or test related to objectives to elicit conceptual understanding. Sometimes, the teacher also gave homework if there was not enough time to practice problems or activities in the class.

The teacher's assessment knowledge during the teaching of the simple machines had similar assessment patterns with the work and energy topic. The teacher elicited the student's prior knowledge about simple machines by using questioning owing to the fact that the students might have alternative conceptions. During the teaching of mechanical advantages of simple machines, the teacher monitored each student's performance because mechanical advantages involved learning difficulties which change from one topic to the other. The teacher also used problems including mathematical calculation to enhance meaningful learning, and she checked each student's performance. If there was a problem about understanding the related topic, she immediately corrected the misunderstanding. Moreover, she gave many tests or quizzes at the end of topics.

Table 4.7. Summary of the Teacher's Knowledge of Assessment

Topics	Dimension of science learning	Method of assessment	The way of assessment	Types of questions	Time of the assessment
Work and energy Simple machines Friction force	Prior knowledge	Questioning	Informal	Open-ended	At the beginning of the class
	Content conceptual understanding	Observation of learning performance	Informal	Open-ended	During the teaching
	Content conceptual understanding	Quiz or test	Formal	Open-ended Multiple choice items	At the end of the topic
	Content conceptual understanding	Homework	Formal	Open-ended Multiple choice items	At the end of the topic
	Grading the students	Unit test or exam	Formal	Open-ended Multiple choice items	At the end of the unit

The topic of friction force was also assessed by the teacher in a similar pattern. However, at the end of the unit, the students had exam to be graded. As a result, the teacher used different assessment methods from at the beginning of the class to at the end of it. She also used different kind of assessment, and Table 4.7 summarizes the teacher's knowledge of assessment.

4.3 The Findings of the Interaction of the Teacher's PCK Components

This part involved the results of the interaction of PCK components. In other words, this part answered the second research question and sub-questions. The interaction of teacher's PCK components comprised of two parts; in the lesson planning and practicing while teaching the topics of work and energy, simple machines, and friction force.

4.3.1 The Interaction of the Teacher's PCK Components in Planning

The first part of the interaction of PCK's components was related to lesson planning. When analyzing the interaction of the teacher's PCK components, the only CoRe lesson plans and pre-interviews were used as data sources. The teacher was asked to design CoRe lesson plans before teaching work and energy, kinetic and potential energy, simple machines, and friction force. Each CoRe plan was analyzed in terms of PCK components and then, the teacher's knowledge interactions were coded. Table 4.8 shows the interaction codes, the reasons for interactions, and explanation of the codes.

When it comes to analyzing interaction of the teacher's PCK components, five kinds of interactions were determined. The first one was related to the teacher's goals for teaching. The teacher's goals were coded as STO owing to the fact that the teacher designed her teaching to introduce science concepts for conceptual understanding. Thus, the interaction appeared between STO and KoC.

Another example was that the teacher planned to apply instructional strategies to teach related science concepts. In this example, STO interacts with KoIS. Table 4.8 shows the detail information about interaction categories and their explanations of the related components.

The second interaction type between PCK components was coded as inform which refers that selecting or using a component required to know an appropriate decision making process. The teacher had knowledge about a component, and this knowledge helped for selection of instructional strategies, activities, or precautions in order to provide students with meaningful learning related science concepts. For example, the teacher had instructional decisions based on students' learning abilities. In this example, the teacher's knowledge of students' learning abilities shaped the selection of instructional strategies, namely KoL interacted with KoIS. Another example of inform interaction categories was the interaction that occurred between KoL and KoIS again. In order to handle students' lack of prior knowledge, the teacher selected more appropriate instructional strategies. In this example, the teacher's knowledge about students' prior knowledge shaped applying teaching strategies.

Table 4.8. Interaction of the PCK Components' Codes and Their Explanations

Codes	Explanation of codes
STO-KoC	The teacher's goal is to teach curriculum objectives or enriched activities.
STO-KoL	The teacher's goal is to teach prior knowledge of related topic in order to provide meaningful learning, or in order to enhance students' abilities; creativity, reasoning, and thinking.
STO-KoIS	The teacher's goal is to apply student-centered instructional strategies in order to enhance students' conceptual understanding.
STO-KoA	The teacher's goal is to assess the students' learning at the end of the course.
KoC-KoL	In order to apply enriched activities, the students should have prior knowledge about related concepts.
KoC-KoC	Considering curriculum limitations as enriched activities
KoC-KoIS	Using particular strategies while teaching particular topics
KoL-KoC	Gifted students need to engage in enriched activities. The topics could be extended to enriched topics by gifted students' questions. Assessing students' prior knowledge based on grade levels.
KoL-KoIS	Using instructional strategies based on student's learning styles. Using instructional strategies in order to overcome the lack of students' prior knowledge. Student-centered instructional strategies or more concrete evidence/examples should be applied because of gifted students in class.
KoL-KoL	It is difficult to deal with misconceptions because of characteristics of gifted students. The students have knowledge about upper grade topics because of characteristics of gifted students.
KoL-STO	Students don't have difficulties to understand science concepts because of characteristics of gifted students. Lack of students' prior knowledge blocks understanding of science concepts.

Table 4.8. Interaction of the PCK Components' Codes and Their Explanations (Continued)

Codes	Explanation of codes
KoL-KoA	To prepare assessments based on gifted students' knowledge level.
STO-KoA-KoIS	In order to reach the teacher's goals, the teacher assesses the students by using related instructional strategies.
KoL-STO-KoIS	Because of characteristics of gifted students, argumentation is an appropriate instructional strategy in order to reach the teacher's goals.
KoL-KoIS-KoA-KoIS-KoA-KoIS	If a topic is not understood by the students, in order to enhance understanding, the teacher applies varies kinds of strategies and assess the students' learning.
KoL-KoIS-KoA-KoIS	If a student has lack of knowledge about any concept, in order to enhance understanding, the teacher applies varies kinds of strategies and assess the students' learning.
KoIS-KoA-KoIS	In order to determine and overcome misconceptions, the teacher uses appropriate instructional strategies.
KoL-KoC-KoIS-KoA	The teacher uses instructional strategies to handle learning difficulties arising from enriched activities.
KoL-KoIS-KoA	The teacher uses instructional strategies to check the students' prior knowledge.
KoL-KoIS-KoA	The teacher uses instructional strategies to determine the students' misconceptions.
STO-KoC-KoL	The teacher's goal is to apply enriched activities, but some students might not be successful because they don't like the activities.

The third interaction code was related to pre-requirement of instructional decision. In order to apply enriched activities, the students should have prior knowledge which requires to be known for meaningful learning. In this respect KoC interacted with KoL. One example appeared in the interaction between KoL and STO. In here, the interaction was coded from decision-making segment that lack of students' prior knowledge blocks understanding of science concepts. Thus, it was a pre-requirement for the teacher to deal with the students' prior knowledge. Moreover, another example of interaction appeared in the category of re-requirement coding as KoL-KoC-KoIS-KoA. This meant that in order to provide meaningful understanding, the teacher used instructional strategies to handle learning difficulties arising from enriched activities.

The forth type of interaction was found in gifted category. The teacher determined her instructional decision for her gifted students. Namely, the students affected the teacher's plan, and she considered her students' characteristics while designing her teaching. For example, the teacher considered the student-centered instructional strategies because the gifted students were bored by lecturing. In this respect, KoL and KoIS interact together. Another example was seen in interaction between KoL and KoL. It was difficult to handle related misconceptions owing to the fact that the gifted students did not accept the teacher's explanations easily as correct knowledge. The teacher must give more concrete knowledge and examples while handling related misconceptions. Another example in this category was that the teacher prepared the evaluation questions based on the gifted students' knowledge and abilities level, so KoL and KoA interact together. Moreover, the students needed to engage in enriched activities since they were gifted, which indicated the interaction between KoL and KoC.

The last category included interactions of PCK components with more than two interactions. Table 4.8 shows each interaction in this category. The teacher generally planned to start new topic by using questioning technique in order to determine students' prior knowledge, and this instructional decision included three PCK components' interactions and was coded as KoL-KoIS-KoA. Similar interaction category was found in determination of students' possible misconceptions related concepts. If the teacher found any misconceptions about particular science topics, she would try to handle them by using lecturing and assess whether the misconceptions were fixed with the correct information or not. If there were still misconceptions, she would change her instructional strategies, and then she would try to handle misconceptions for the second time. This instructional decision was coded as KoIS-KoA-KoIS. According to Table 4.8, there is a code related to six PCK components' interactions as KoL-KoIS-KoA-KoIS-KoA-KoIS. This instructional decision was that the students did not understand a topic taught by the teacher. When the teacher explained a concept by using lecturing and the students did not understand, the teacher changed the instructional strategy, and she tried to explain it by giving more concrete examples. If there was still a problem for students understanding, the teacher changed again her strategies and she tried to use demonstration by using lab materials. If the same problem continued, she tried to engage students in hands-on lab application. She hoped that using lab activities enhances the student's conceptual understanding.

4.3.1.1 Comparing and Contrasting each Interaction Map in the Planning

Figures of 4.12, 4.13, 4.14, and 4.15 show the teacher's PCK maps while she was planning topics work and energy, kinetic and potential energy, simple machines, and friction force. Each figure includes two mapping approaches such as Map A: The study mapping approach which was developed by researcher and Map B: Pentagon model developed by Park and Chen (2012). Pentagon model was used in this study in order to make the frequencies of interactions for readers more comfortable and easy to see. Due to the fact that the study mapping approach maps involve the large number of interactions and detail presentation each of them, it might be difficult to calculate the frequencies of interactions in the study mapping approach.

While creating each map, CoRe plans and pre-interviews were analyzed and coded to form the categories in Table 4.8. The CoRe plans and the interviews questions shaped PCK maps and how the components flow due to the fact that the teacher designed her CoRe plans to answer the same order questions.

For example, the first questions in the CoRe plan are: why you choose the big idea for teaching related topics and what you target the students to learn about the big idea. These questions helped determining the teacher's STO. Thus, all PCK maps started the interaction of STO with other components generally KoL and KoC. The components which proceeded in direction of the arrow are the first component for the interaction categories. Other components interacted with the first component and branched up and down in the map were formed according to the teacher's answers to each CoRe plan questions illustrated in the Map A in Figure 4.12. The numbers in the PCK maps showed the order of the teacher's decision process while she was preparing her lessons.

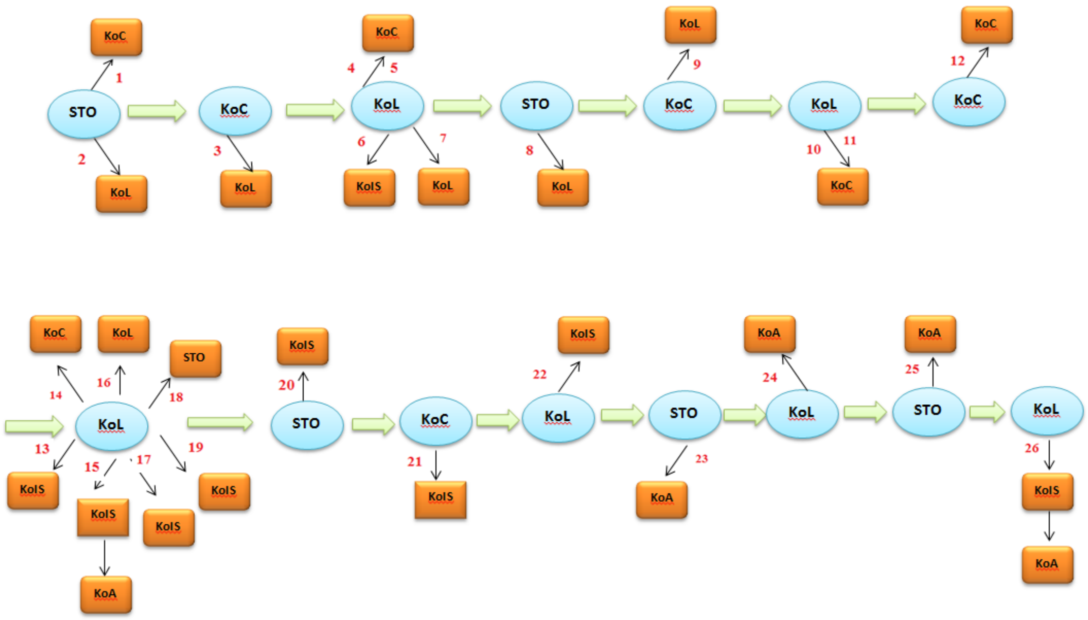
Map A in Figure 4.12 shows that the teacher's PCK map of work and energy involved 15 decision making segments, and STO acted 5 times as an initiative component as illustrated in Map B: Pentagon model in Figure 4.12, KoC acted 4 times, and KoL became on initiative component 6 times. However, KoIS and KoA were not considered as initiative components in planning the topic "work and energy".

STO appeared at all the stages of class, because this component reflected the teacher's goal and proposes in the planning map. For example, when the first interaction in Figure 4.12 is considered, the interaction between STO and KoC reveals that the teacher explained curriculum objectives in order to introduce the topic "work and energy". Then, in the eighth interaction, the teacher explained her overall aim as the development of the students' knowledge and abilities. Moreover, in the interactions 20 and 23, the teacher described her aim of using instructional strategies and assessment, respectively.

KoC appeared between the third and the 21st interactions. The third interaction means that in order to apply enriched activities, the students should have some prior knowledge of the related concepts. The ninth interaction revealed that the gifted students need enrichment activities and the 12th interaction explained that the teacher considered curriculum limitations as enriched activities. Finally, in the 21st interaction defined using particular strategies while teaching particular curriculum concepts.

KoL was the most interacting component in the topic "work and energy", and it appeared during all the stages of planning process. The interactions from the fourth to the seventh were related to the relationships between students' prior knowledge and curriculum objectives or between the instructional strategies and the student's learning styles or between students' knowledge levels and the characteristics of gifted students (as seen in Table 4.8 in detail).

Map A: The study mapping approach



Map B: Pentagon Model

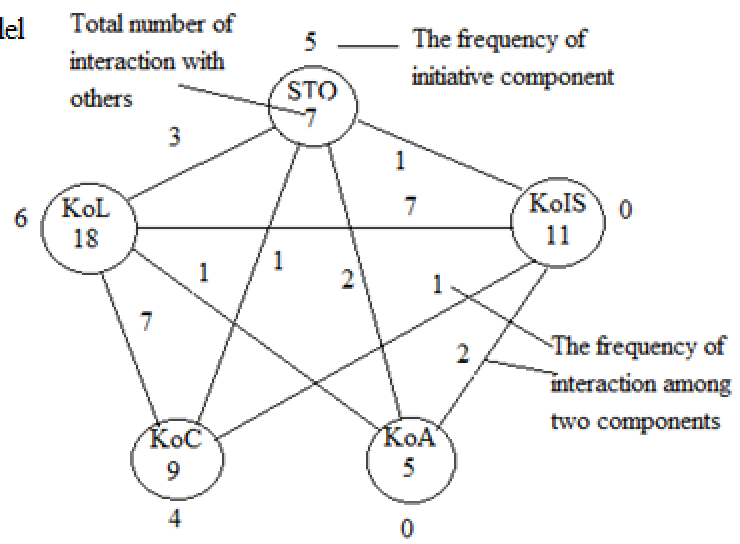


Figure 4.12. Teacher's PCK Maps While Planning Work and Energy

Moreover, the 10th and 11th interactions explained that the gifted students need to engage in enriched activities and the topics could be extended so as to enrich the topics according to the questions of the gifted students. On the other hand, the decision making segment including the interactions from the 13th to 19th had more complex structure than the others, because the teacher tried to overcome students' possible misconceptions and learning difficulties caused mainly by the characteristics of the gifted students and the enrichment activities. Finally, the interactions 22, 24, and 26 indicated the relationship among students' characteristics, instructional strategies and assessment.

KoIS and KoA did not appear as an initiative component, but they interacted with other components frequently as secondary components. Surprisingly, KoIS was the second most interacting component and it interacted 11 times (as seen in the rectangular boxes in Map A in Figure 4.12). KoA interplayed 5 times, KoC interacted 9 times and KoL interacted 18 times. On the other hand, both KoIS and KoA began to appear after the middle part of planning process where the teacher reflected her decision making about the instructional strategies (except the interaction 6).

Regarding planning the topic "kinetic and potential energy", Map A in Figure 4.13 indicates eight decisions making segments. Three of them are related to STO, and it reflects the teacher's goals and purposes. Similar to STO, KoL acted as initiative component and interacted three times during planning process. On the other hand, KoC and KoIS interplayed one time as initiative component. KoIS was only specific for this topic and it explained that the teacher used appropriate instructional strategies, in order to determine and overcome misconceptions. Furthermore, KoIS interacted as a secondary component 13 times with other components 17 times and it was the most interacting components. It also often appeared after the seventh interaction as seen in Map A in Figure 4.13.

In contradistinction to PCK map of work and energy, kinetic and potential energy includes much more branched interactions as seen from the seventh interaction to the 17th in Map A in Figure 4.13. The seventh and the eighth interactions focused on enrichment activities and the teacher considered that the students would have possible learning difficulties or misconceptions about calculating the amount of kinetic and potential energy. Then, she planned to overcome those difficulties by using appropriate instructional strategies. Similarly, the tenth interaction showed that the teacher used instructional strategies to handle learning difficulties and assessed the effectiveness of her teaching. Moreover, interaction 11 explained that if there was a learning difficulties or lack of knowledge, the teacher would use a particular instructional strategies and she would assess. After all, if the difficulties still persisted, she would change her instructional strategy.

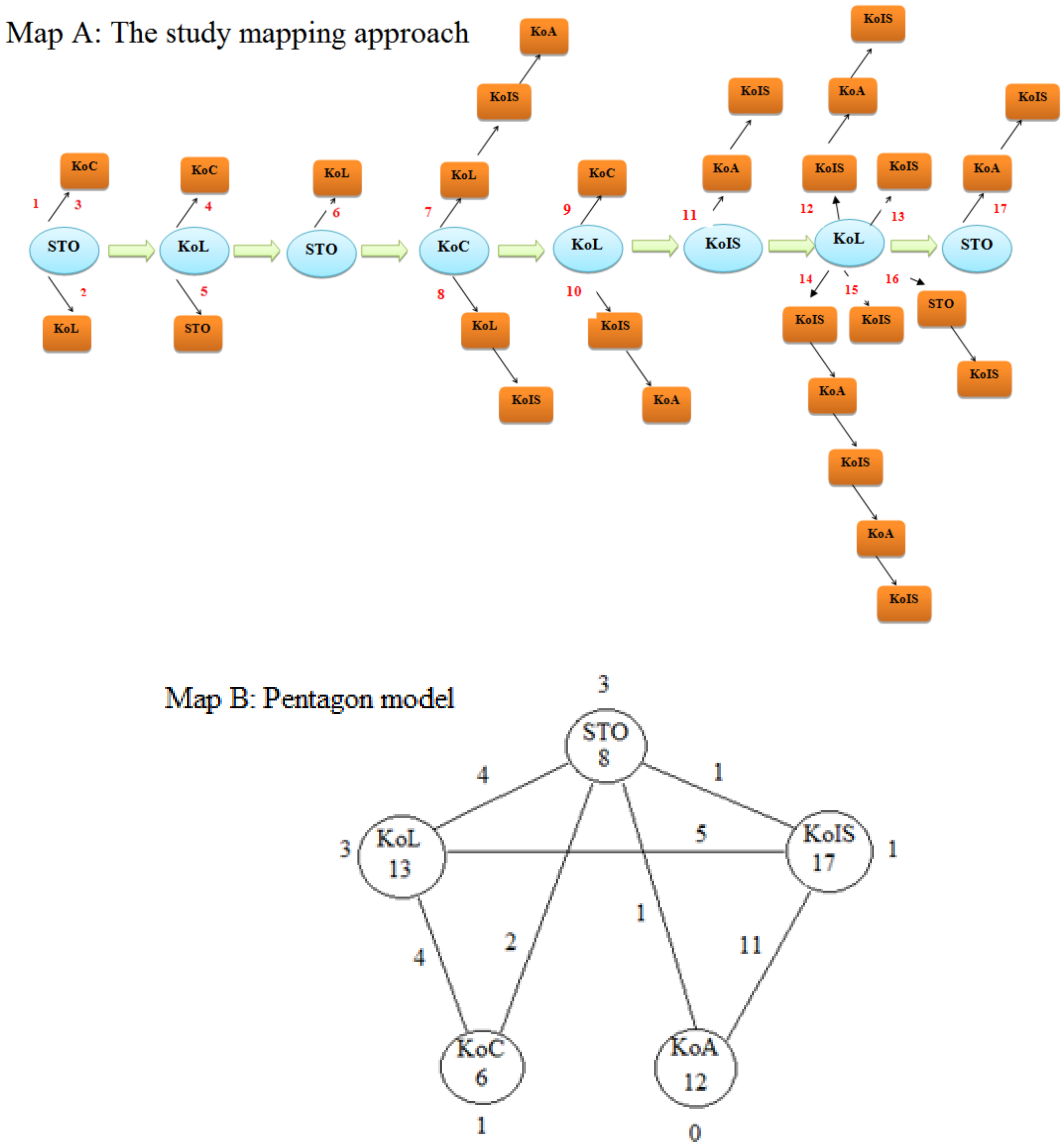


Figure 4.13. Teacher's PCK Maps While Planning Kinetic and Potential Energy

Finally, interaction 14 was highly apparent and complex. It referred that if a topic was not understood by the students, in order to enhance understanding, the teacher would apply varies kinds of strategies and would assess the students' learning. Moreover, the pentagon model in Figure 4.13 shows the frequencies of interactions and initiative components. In this model, KoA did not connect with KoC and KoL. KoC also did not interact with KoIS.

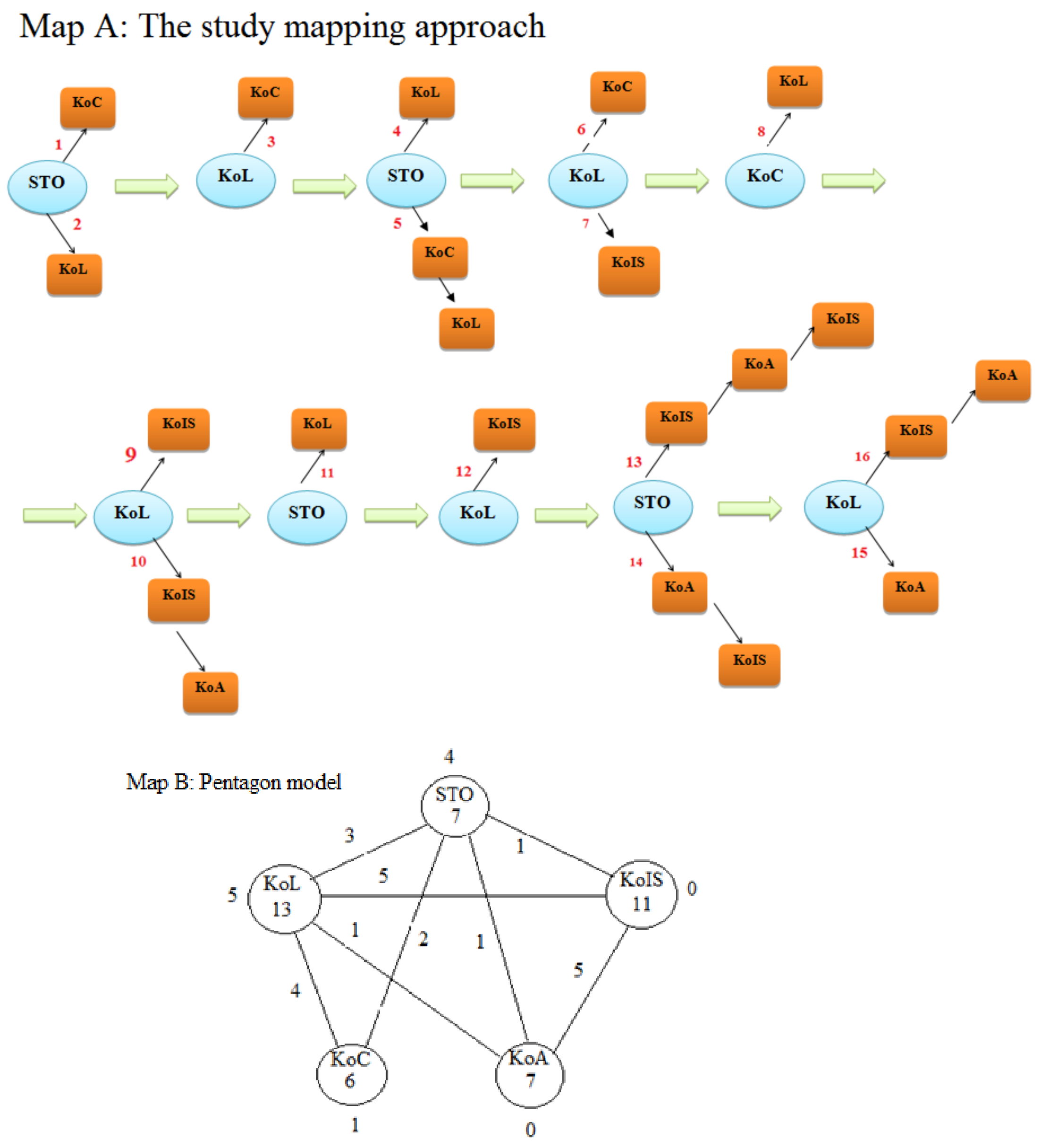


Figure 4.14. Teacher's PCK Maps While Planning Simple Machines

As seen in Figure 4.14 teacher PCK map about simple machines, similar to previous two maps, STO, KoL, and KoC were initiative components. Total number of decision making segment is 10. Moreover, STO appeared during all the stages of planning and interacted four times. It also referred to the teacher's goals and purposes in terms of selecting objectives, instructional strategies, enrichment curriculum, and assessment. KoL played an important role similar to other maps and it interacted five times during all part of decision making process. On the other hand, KoC interacted only one time as initiative component with KoL, which referred that the students should have prior knowledge about related concepts in order to apply enriched activities.

This PCK map had less level of complexity in terms of interactions than PCK map about kinetic and potential energy but more complex than PCK map about work and energy. The work and energy map yielded much more binary interactions such as KoL-KoC or KoIS-KoA, whereas the simple machines map outnumbered in terms of complex interactions such as STO-KoC-KoL or KoL-KoIS-KoA. Similar to previous two maps, KoIS was the most interplayed as a secondary component and it appeared after the seventh interaction which meant that the teacher used particular strategies in order to overcome students' learning difficulties or lack of knowledge. Moreover, similar to other maps, KoA played important role, after interaction 10, in assessing the effectiveness of instructional strategies and students' conceptual understanding.

The friction force maps have the least interactions as illustrated in Figure 4.15. There are 5 initiative components and total number of interaction is eight. Similar to other PCK maps, STO and KoL played essential role as initiative components three times and two times, respectively. STO reflected the teacher's goals and purposes while selecting objectives, enrichment activity, particular strategies, and assessment. KoL interacted with KoC in order to link between students' prior knowledge and enrichment activities. KoL also interplayed with KoIS so as to overcome students' learning difficulties and misconceptions.

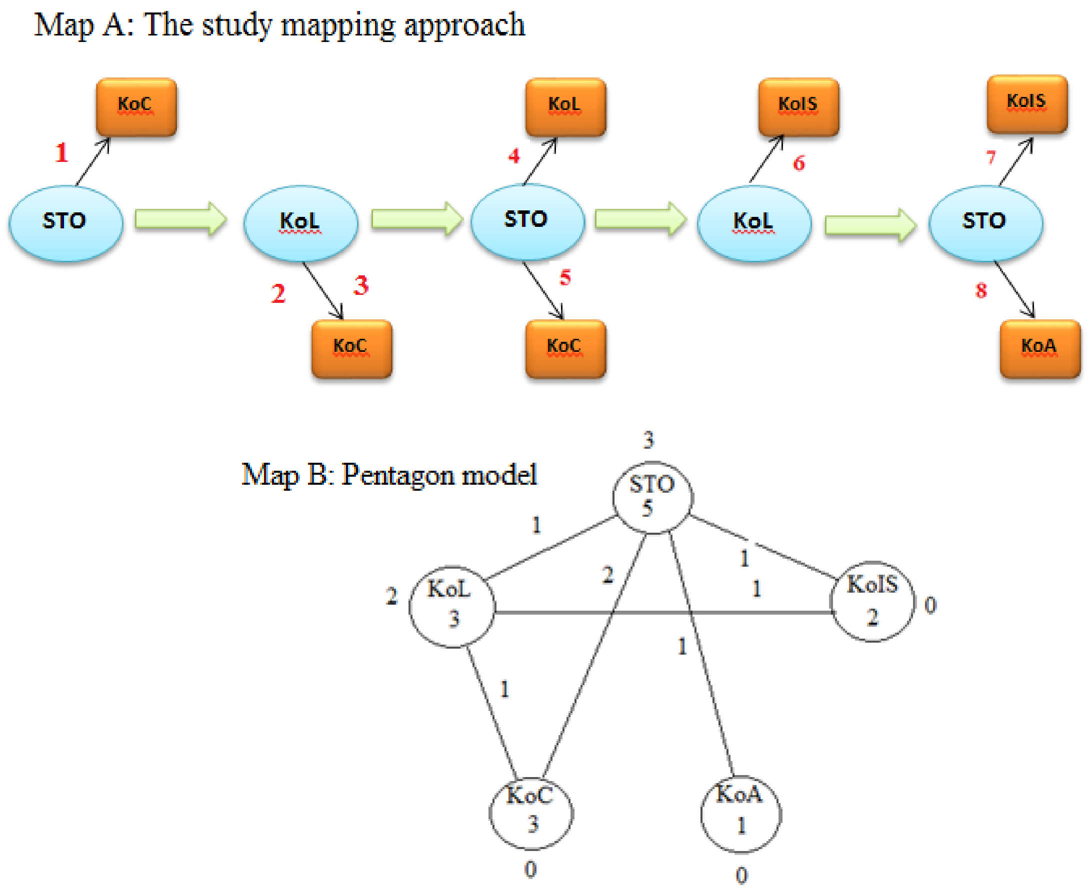


Figure 4.15. Teacher's PCK Maps While Planning Friction Force

As a summary, when it comes to analyzing PCK map, STO interacted with all PCK components in the maps. Since PCK maps were related to planning stage, generally KoL and KoC components more interacted than other components. The knowledge of characteristics of gifted students' in the KoL and knowledge of enrichment curriculum in the KoC played a more dominant role than other components and these two sub-components shaped the teacher decision making process. Moreover, each PCK map had different characteristics based on the nature of the topic. One topic includes concepts with different level of complexity which can be difficult to learn for students. Another topic included many possible alternative conceptions and learning difficulties. Each learning difficulty should be handled by the teacher in planning stage. If the topic includes alternative conceptions or learning difficulties, the teacher would plan to overcome them by using some precautions. Concordantly, if the teacher faces a lack of knowledge in the students, she should plan what kind of strategies to use and assess the outcomes. These precautions were interplayed in triple and quadruple way (see detail Table 4.8). On the other hand, some topics such as friction force's maps in Figure 4.15 include the least interactions because the topics had less objectives, alternative conceptions and learning difficulties compared with other topics.

4.3.2 The Interaction of the Teacher's PCK Components in Practicing

When it comes to analyzing interactions of the teacher' PCK components in teaching, the observations data and post-interview of CoRe plan were used for each lesson. The interaction of the teacher's knowledge was coded as follows: The teacher started the lesson by using questioning technique in order to assess the students' prior knowledge and determine their alternative conceptions.

This teacher's pedagogy was coded as interaction between KoIS and KoA. Then, the teacher tried to lesson objectives desired to be taught and this interaction was coded as KoIS-STO. While teaching related concepts, there was a lack of prior knowledge or learning difficulties. So as to overcome these deficiencies, the teacher used an appropriate instructional strategy. The pedagogy was coded as interaction between KoIS and KoL. Another interaction revealed that the gifted students elaborated the related concepts by using inquiry, which led the teacher to engage the students in enriched activities through an appropriate instructional strategy. This pedagogy was coded as KoL-KoC-KoIS. Moreover, the teacher assessed the students' performance during lesson by using questioning or assigning the related problems. Some problems or questions led to learning difficulties for students. In order to handle them, the teacher tried to revise the problem or selected an appropriate instructional strategy. This pedagogy was coded as KoIS-KoA-KoL-KoIS. Table 4.9 and Figures from 4.16 to 4.28 show the detail explanation about PCK maps, codes, and categories while the teacher's teaching practices of work and energy, simple machines, and friction force.

Table 4.9. Interaction of the PCK Components' Codes and Their Explanations

Codes	Explanations
KoIS-KoA	Assessing students' prior knowledge or conceptual understanding by using specific instructional strategies
KoIS-KoL	In order to overcome the lack of pre-requirements or alternative conceptions by using specific instructional strategies. In order to make abstract concepts more concrete by using specific instructional strategy Using particular instructional strategies to handle learning difficulties
KoIS-STO	Teaching the objectives related to teacher's goals and purposes by using specific instructional strategies
KoIS-KoC	Teaching enrichment curriculum concepts by using specific instructional strategies
KoA-STO	Using particular assessment techniques in order to evaluate if the students have reached teacher's goals and purposes.
KoC-KoL-KoIS	Using particular instructional strategies to deal with learning difficulties resulting from enrichment activities.
KoL-KoC-KoIS	Characteristics of gifted students in enriched activities lead to more questions, which are answered by using specific instructional strategies.
KoIS-KoL-KoIS	While teaching a topic by using a specific strategy, a learning difficulty occurs. In order to overcome that difficulty, teacher changes the instructional strategy or supports additional instructional technique.
KoIS-KoA-KoL-KoIS	In order to make assessment, teacher asks the questions. Then learning difficulties occur. So as to handle those difficulties, teacher revises questions or explains them.
KoIS-KoC-KoA-KoL-KoIS-KoL-KoIS	Teacher uses a specific instructional strategy to explain an enrichment activity. While assessing enriched activity, learning difficulties occur. In order to handle those difficulties, teacher uses different examples and explanations. If there are still learning difficulties, as a last step, teacher selects another instructional technique.

4.3.2.1 Comparing and Contrasting each Interaction Map in Practicing

When looking at PCK maps about work and energy in Figure 4.16, there are three teaching segments and 11 interaction branches in Map A. The objectives of this topic, the teacher intended to teach, included that students could able to explain the relationships among force, work, and energy and they were able to define physical work and its units. Therefore, KoIS acted two times as initiative component.

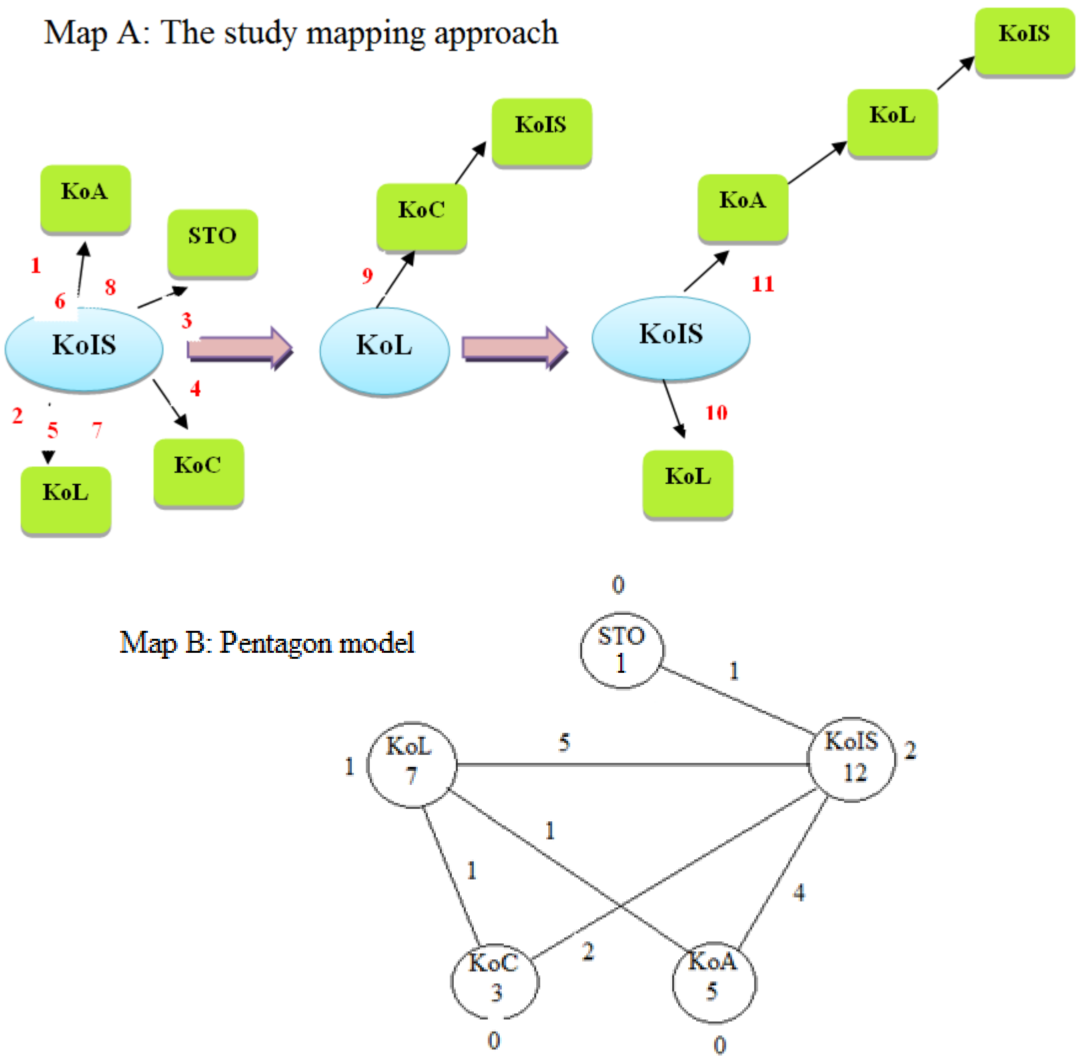


Figure 4.16. Teacher's PCK Maps While Practicing Work and Energy

In the first teaching segment, the teacher used eight interactions in order to assess students' prior knowledge and effectiveness of her teaching about work and energy, introduce what work was, make abstract concepts more concrete, and offer enrichment activity. This segment displayed much more interactions than others because the teacher dealt with the misconception about physical work and work done in the daily life. In the second teaching segment, there were learning difficulties about work done by resultant force arising from enriched activity. The teacher tried to overcome them by using particular strategies. Finally, the third teaching segment was related to teacher assessment about her teaching. She used questions to determine the students' conceptual understanding and she struggled some learning difficulties by using particular instructional strategies.

Due to the fact that this map derived from the teacher's teaching practicing, KoIS was used more than others. KoL only used one time as an initiative component and it was related to the characteristics of the gifted students causing the teacher to introduce enriched activity. On the other hand, STO (one time), KoA (four times), KoC (two times), KoL (five times), and KoIS (two times) were interacted as a secondary component during her teaching.

When looking at Map A in Figure 4.17 the topic "kinetic energy", there are five initiative components comprising of three times of KoIS, one of KoL, and one of KoC. The teacher started her lesson to assess students' prior knowledge about kinetic energy by using questioning technique as seen in the first interaction. Then she put target objectives into practice by using lecturing. After all, learning difficulties appeared and she tried to overcome them. In this teaching segment, KoIS played an active role. On the other hand, KoL in the second teaching segment was used to determine that the students needed enrichment activities so she offered them. The teacher realized that enrichment concepts led to some learning difficulties in the fourth teaching segments, and then, she explained them by using specific instructional strategies. In other words, the sub-components of the characteristics of gifted students and enrichment curriculum influenced her teaching.

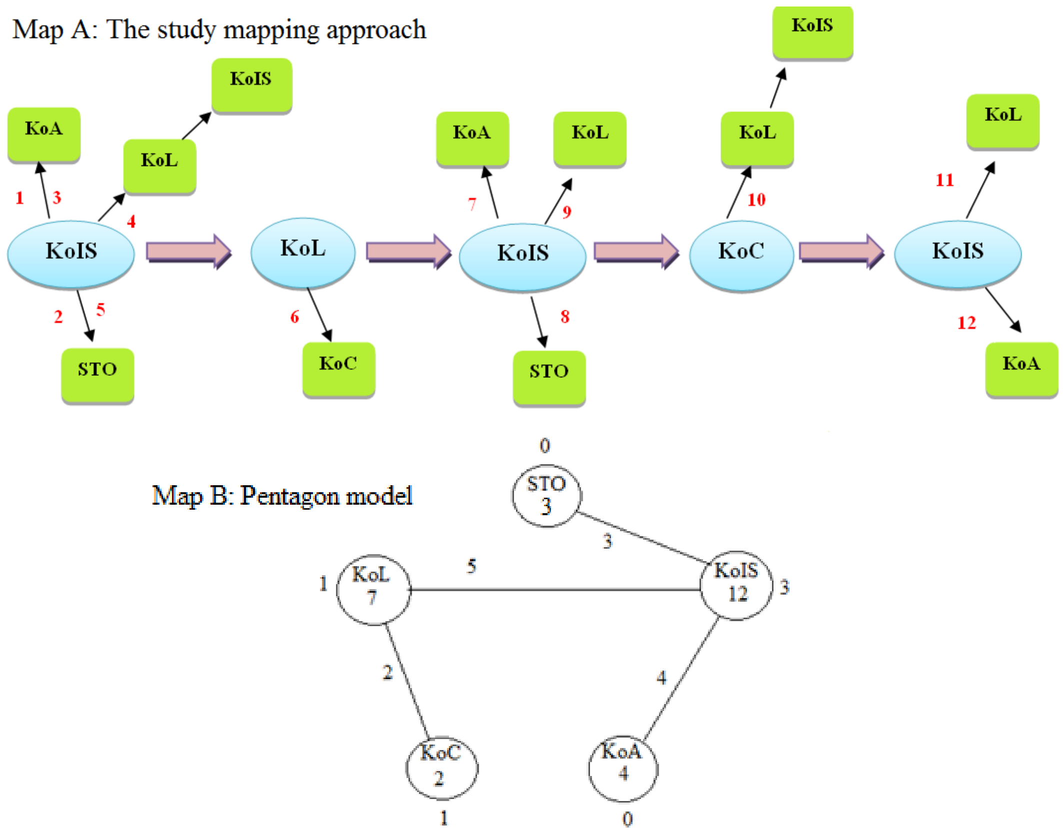


Figure 4.17. Teacher's PCK Map While Practicing Kinetic Energy

While teaching kinetic energy, the teacher used other components as a secondary interacted component. For instance, STO was used two times in order to introduce targeted concepts and enrichment activities, KoA was used three times so as to determine students' prior knowledge and conceptual understanding, KoC was used one time to offer enrichment activity, KoL was used four times in order to realize the students' learning difficulties, and KoIS was used two times to make concepts more clear.

When comparing the Map A of kinetic energy with previous map of work and energy, they have similar feature in terms of complex interactions and they have approximately same number of interactions. In other words, the teacher reflected the same degree of challenges while teaching the two topics.

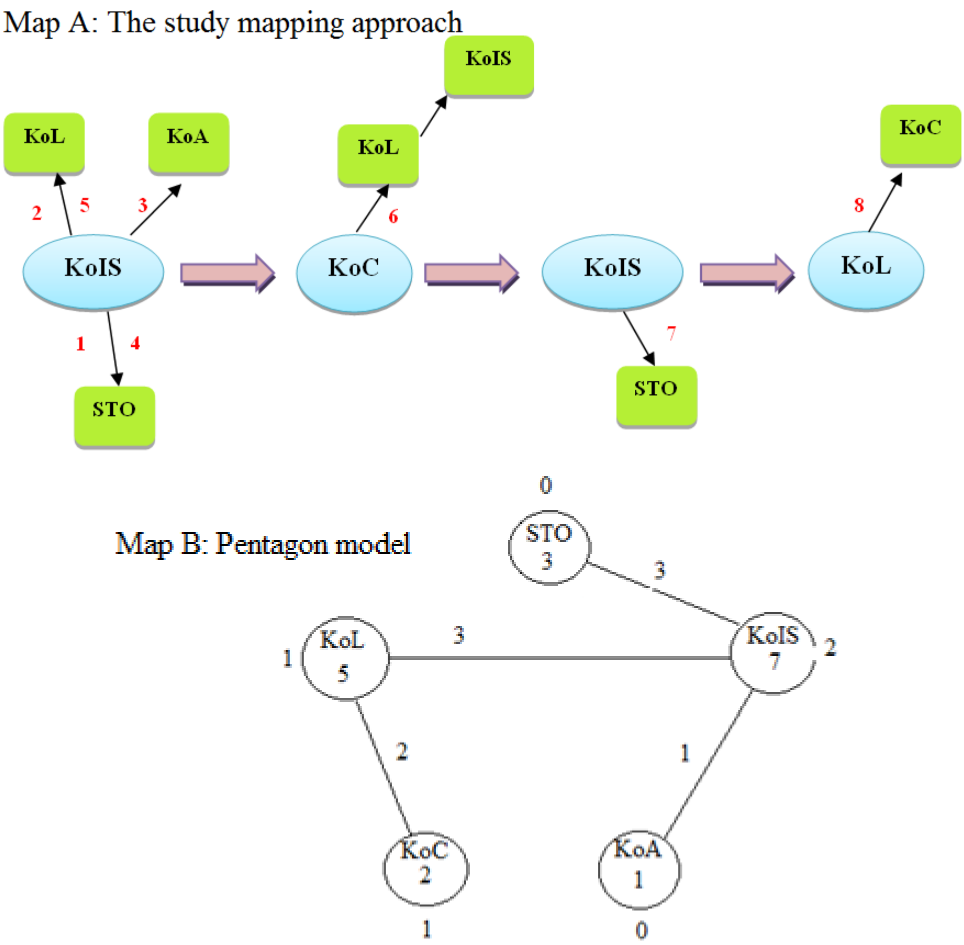


Figure 4.18. Teacher's PCK Maps While Practicing Potential Energy

Similar to the topic "kinetic energy", potential energy had general teaching pattern such as the students learned what potential energy was, the relationships between mass and weight affecting potential energy of any objects, and they practiced to calculate the magnitude of any objects' potential energy. However, the maps of potential energy (as seen in Figure 4.18) have less complex interactions than kinetic energy maps because the students could transfer previous learning of features of kinetic energy to new learning of potential energy. Therefore, potential energy's Map A includes eight interactions and only one triple interaction (interaction 6, KoC-KoL-KoIS). The interaction explained that enrichment activity (giving formula of P=mgh and calculate potential energy) caused learning difficulties (the students confused the differences between mass and gravity) and then, the teacher explained them verbally. As a result, in the topic “potential energy”, the teacher faced less learning difficulties and experienced less pedagogical difficulties than she did in the teaching of the topic “kinetic energy”.

Similar to previous maps, KoIS (two times), KoC, and KoL (one time) acted as initiative components. Because of the enrichment activity having mass and gravity in the formula of potential energy, KoC was interplayed with KoL (occurring learning difficulties). Moreover, due to the characteristics of the gifted students, they interrogated enrichment concepts (this pedagogy reflected the interaction of KoL-KoC), and the teacher had to explain those concepts. As a result, it was clearly seen that the characteristics of the gifted students had an effect on the teacher teaching practice in the topic “potential energy”.

In contrast to kinetic energy and work and energy maps, potential energy map included less secondary interaction components such as both KoL and STO appeared two times, KoA, KoC and KoIS were used one time. The amount of the secondary interaction components also shows that teaching of the topic “potential energy” was less difficult or complicated than teaching of other topics. In other words, the teacher did not have much difficulty in translating her knowledge and abilities into application level than other topics.

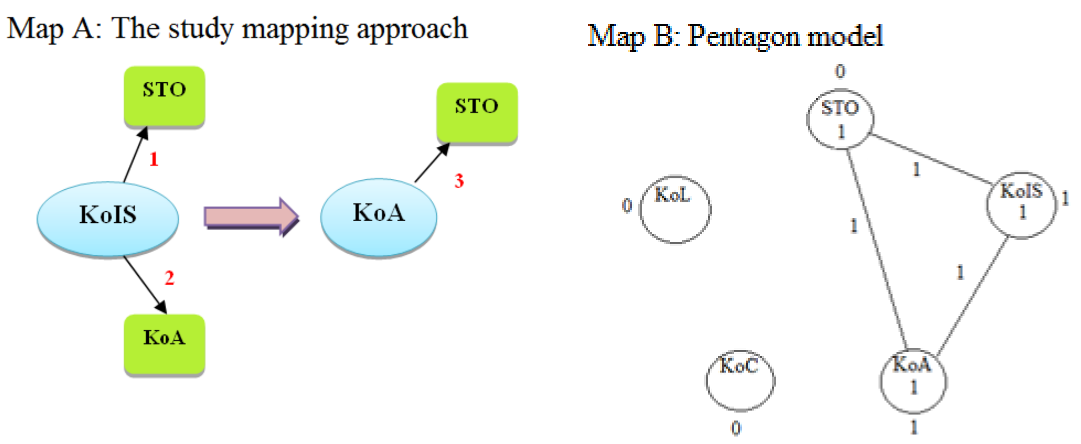


Figure 4.19. Teacher’s PCK Maps While Practicing Conservation Energy

The topic "conservation energy" included two objectives: (a) students will able to explain that potential and kinetic energies can turn into each other, and (b) as explaining energy transformation, students will able to predict that the energy conserves. In order to cover these objectives, the teacher started the topic with asking two questions by drawing (as seen in Figure 4.2). The students could interpret the objects' energy and their transformation from kinetic to potential and from potential to kinetic. After determining of the students' opinion about conservation energy, she continued to explain the topic by lecturing. In this teaching segment as illustrated in Map A in Figure 4.19, KoIS acted as initiative component. In order to assess students' conceptual understanding, she asked additional questions related to the daily life. In this segment, KoA acted as initiative component. Due to the fact that the topic did not include complex content, only STO (two times) and KoA (once) interacted as secondary components.

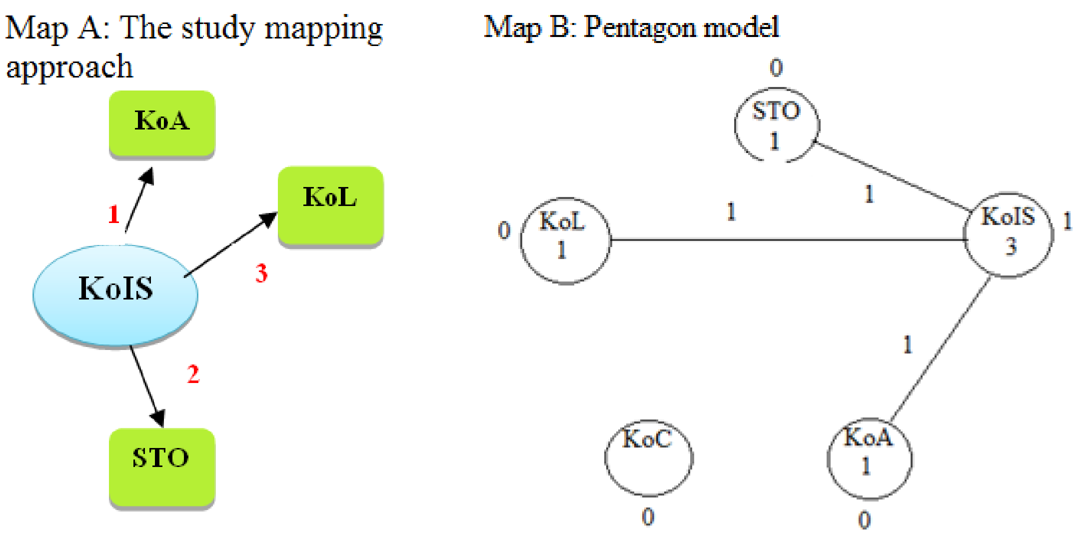


Figure 4.20. Teacher's PCK Maps While Practicing Simple Machines

In contrast to conservation energy and other topics, the introduction of simple machines has less complex contents. It had two objectives: (a) students will able to predict how to change the direction of a force, and (b) students will able to identify the tools used to change the direction and magnitude of a force as simple machines.

Therefore, the teacher started her teaching to determine students' prior knowledge about simple machines. Then, she explained the term of simple machines by using many examples and visuals. Some students believed that machines require including technological aspects such as motors, cables, electrical devices. Thus, this belief yielded some pedagogical difficulties and the teacher tried to overcome them, which is seen in interaction 3 in Map A in Figure 4.20. As a result, only KoIS acted as initiative component and KoA, STO, and KoL were interacted as secondary components only once because simple machine topic included one teaching segment and there was no additional enrichment activity.

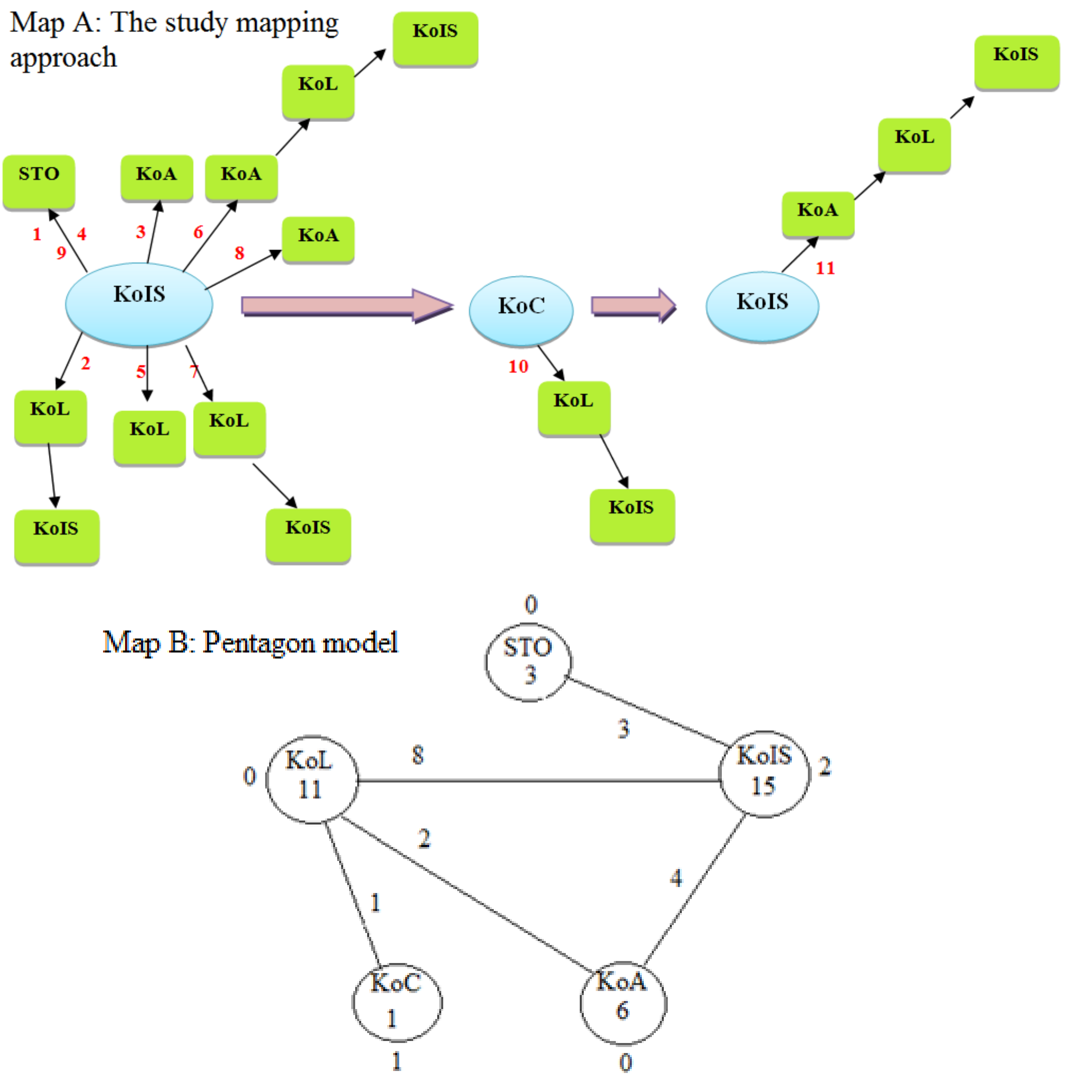


Figure 4.21. Teacher's PCK Maps While Practicing Levers

Levers were taught as the first example of simple machines. Students first faced the mechanical advantages or disadvantages of force and load. Therefore, the levers maps as illustrated in Figure 4.21 have similar complexity of interactions as well as kinetic energy maps and it includes more complex interactions than simple machines, conservation of energy, and other maps. It has three initiative components (two of them is KoIS and one of them is KoC) and 11 interactions. STO interacted as a secondary component one time, KOL was six, KoIS was five, KoA was four times.

The most complexity of interaction appeared in the first segment because the students engaged in laboratory activity to discover the mechanical advantages of levers. After laboratory work, the teacher explained the results of laboratory work. There were some learning difficulties in interactions 2, 6, and 7. Moreover, enrichment activity led to learning difficulties in the second teaching segment. In the last segment the teacher asked some questions in order to assess students' conceptual understanding. As a result, some learning difficulties were appeared and the teacher tried to overcome them by using appropriate instructions.

Similar to levers map (3 triple interactions, 2 quadruple interactions, and total interaction number is 11), pulley interaction map includes two quadruple interactions, one triple interaction, and total number of interactions is 13. Thus, it can be said that these two topics maps include the most complicated objectives, applications, and concepts because the teacher had difficulties during teaching of them. These difficulties were reflected in interactions 3, 6 and 12 for pulleys map as illustrated in Map A in Figure 4.22, and in interactions 2, 6, 7, 10 and 11 for levers map as illustrated in Map A in Figure 4.21.

Similar to other maps, KoIS (two times) and KoL (one time) acted as initiative interaction component. There are three teaching segments, and first and third segment include six and five interactions, respectively. In the first teaching segment, the teacher faced the difficulties to introduce the differences between fixed and movable pulleys. Second teaching segments involves two interactions between KoL and KoC meaning that the characteristics of gifted students demanded enrichment activity such as the students discovered the weight of pulleys affecting the balance of the system and the teacher had to explain it.

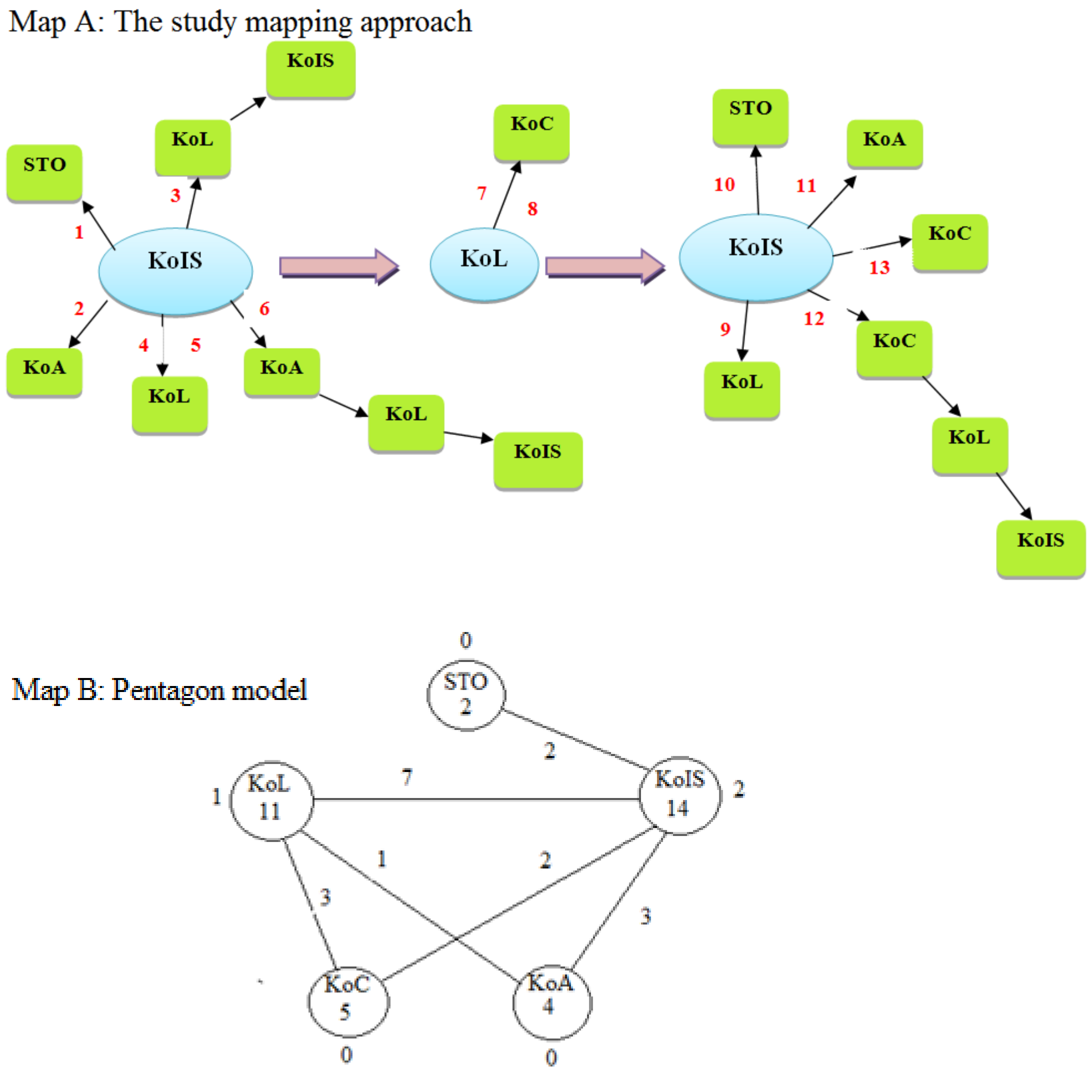


Figure 4.22. Teacher's PCK Map While Practicing Pulleys

The final segment includes more interactions, for example, questioning technique was used to overcome the students' lack of knowledge about pulleys as illustrated in interaction 9, and then the students took notes about pulleys as seen in interaction 10. After introducing pulleys, she asked many questions to assess students' conceptual understanding (interaction 11). Some questions included complex pulleys system and the teacher faced learning difficulties or lack of knowledge. And then, in order to deal with the learning difficulties, she drew the question again and explained it step by step (interaction 12). Finally, she continued to offer enrichment activity questions so as to provide the meaningful learning about pulleys (interaction 13).

The all components were used as secondary interaction components at a similar amount such as STO interacted 2 times, KoA, KoC and KoIS were 3 times, and KoL was 5 times. Using of the secondary interaction components was nearly similar to the topics "levers", "kinetic energy", and "work and energy".

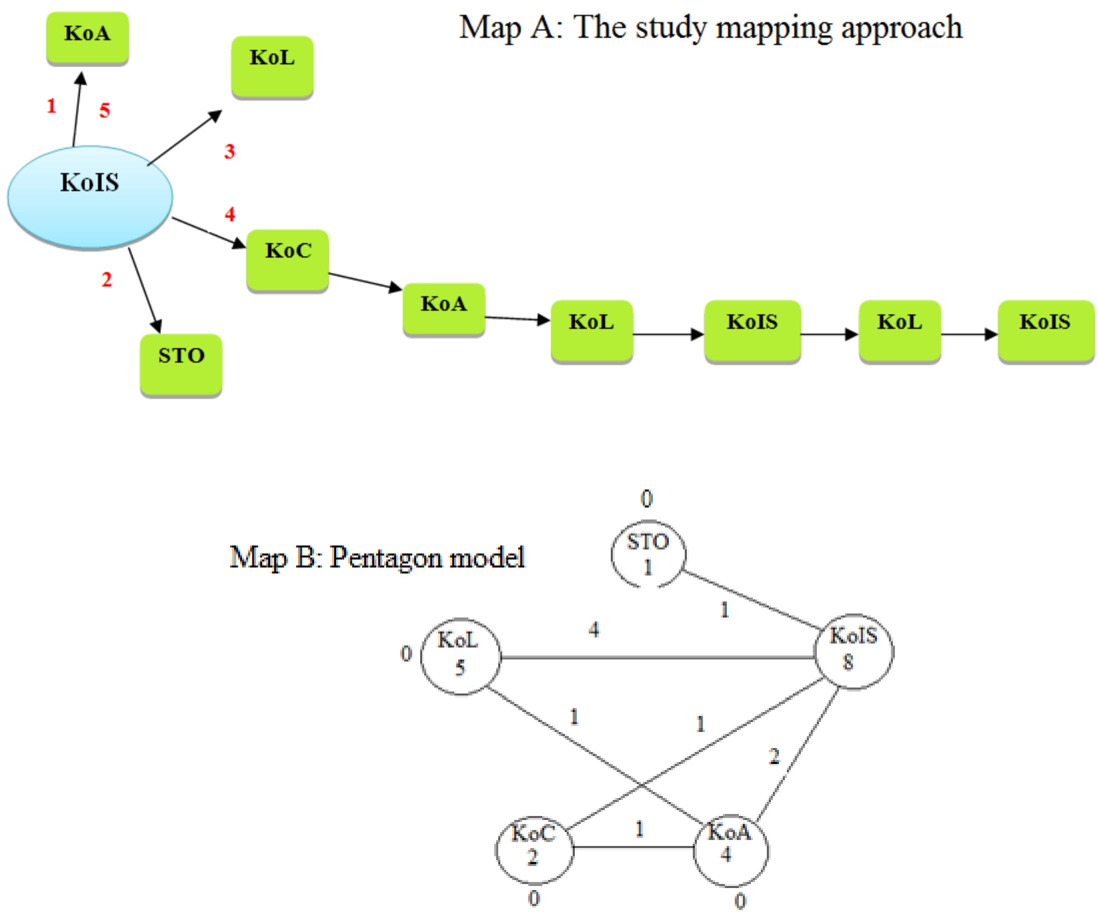


Figure 4.23. Teacher's PCK Maps While Practicing Hoists

Hoists topic is the extension of pulleys so the teacher reflected one teaching segment in order to introduce it. She started to lesson with assessment to control students' prior knowledge about pulleys (as illustrated with interaction 1 in Map A in Figure 4.23). Then, she continued to her teaching with explaining what hoist was and why it was used. After introducing hoist, she asked a question to investigate the relationships between force and load. However, some students had difficulties to understand the relationships between force and load (as seen in interaction 3). Then, the teacher tried to explain hoists by drawing some questions sequential from easy to difficult (as seen in Map A in Figure 4.9). Interaction four shows the teacher's struggle when she explained each question. The interaction also includes the most complex interactions, and there are seven interactions. Finally, the teacher finished the lesson by asking some questions in order to assess students' performance (as seen in interaction 5).

Only KoIS appeared as initiative component, and there are five interactions. KoL was three times, KoA and KoIS interacted two times, and STO and KoC was one time, Similar to other PCK maps, all PCK components interacted to each other in teaching process.

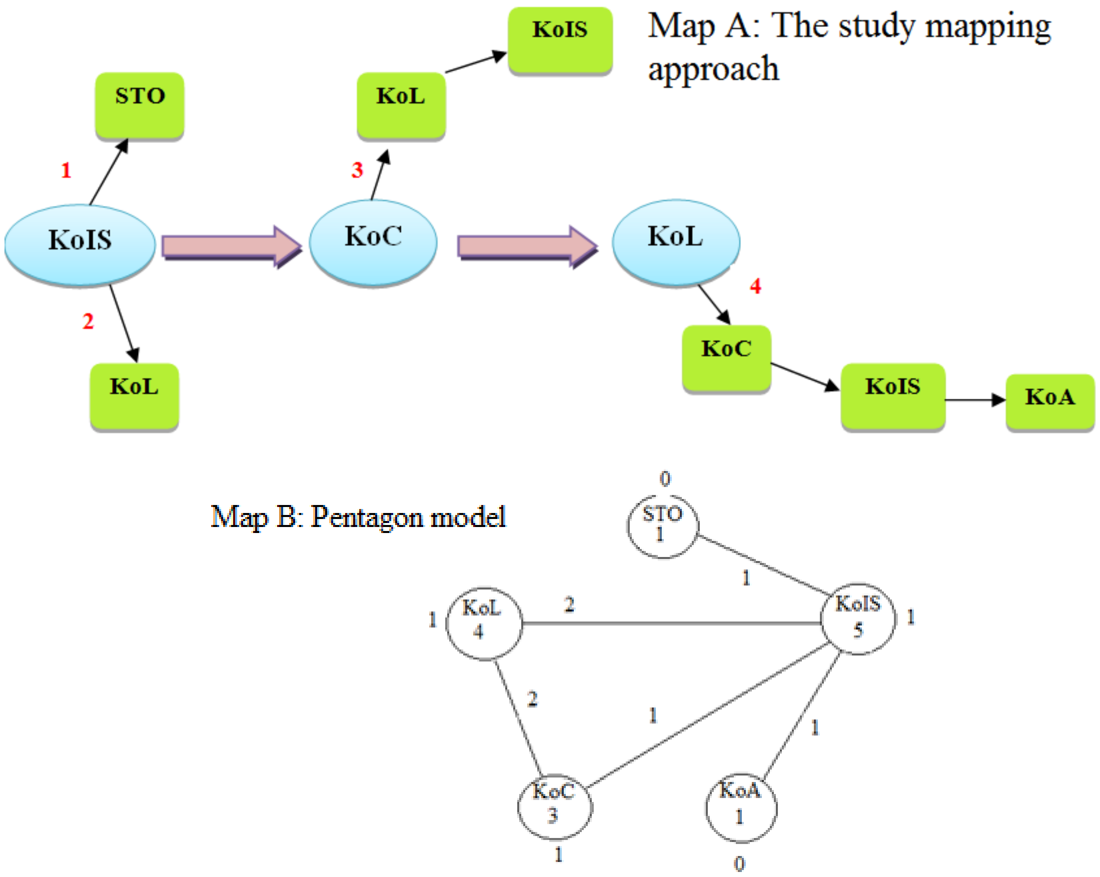


Figure 4.24. Teacher's PCK Maps While Practicing Inclined Plane

The topic "inclined plane" is one of examples of simple machines. It includes complex structure and concepts as well as other topics such as levers and pulleys.

However, the teacher did not face too much pedagogical difficulties compared to other example of simple machines. The inclined plane map has only four interactions and three teaching segments and each segment has one or two interactions. Due to the fact that the students could use previous learning about mechanical advantages and feature of simple machines, they transferred easily the previous learning into new topic of inclined plane. Thus, the teacher did not challenge so much when teaching the topic.

KoIS, KoC, and KoL acted as initiative components once (as seen in Map A in Figure 4.24), and STO, KoA, and KoC were only used by the teacher once as secondary interaction components. On the other hand, KoL and KoIS were involved the teaching segments on two times.

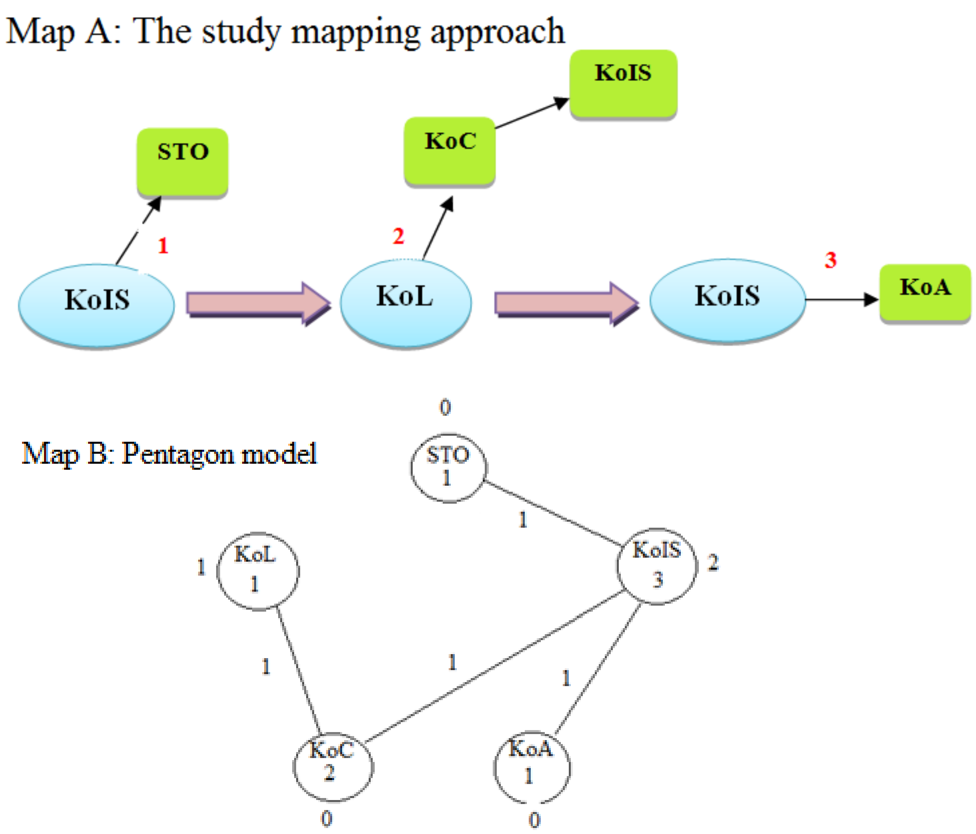


Figure 4.25. Teacher's PCK Maps While Practicing Spinning Wheel

After practicing inclined plane, the students covered the meaning and logic of simple machines. They could understand the applications of mechanical advantages or disadvantages on various kinds of simple machines. Figure 4.25 shows that the teacher used her PCK components only three times during spinning wheel topic. KoIS (two times) and KoL (one time) acted as initiative component and she formed only three teaching segments including only one interaction.

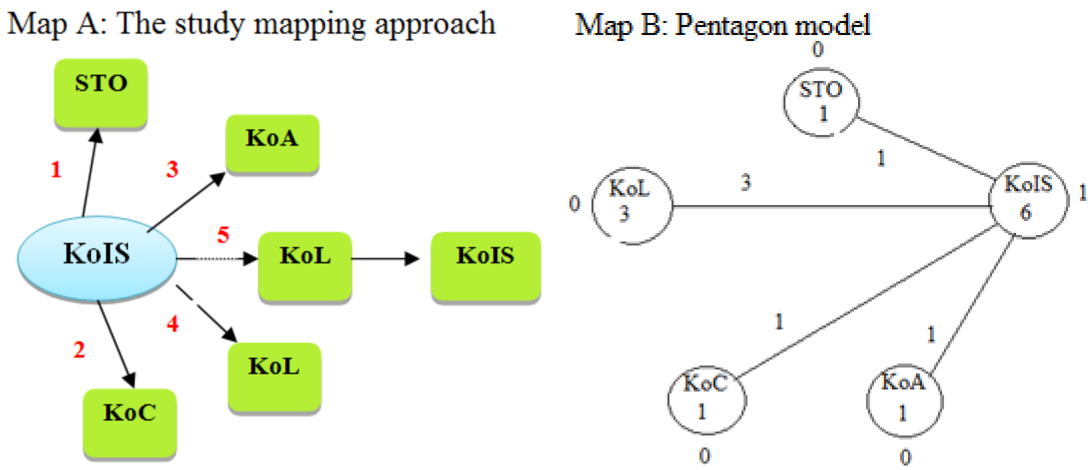


Figure 4.26. Teacher's PCK Maps While Practicing Gears

Similar to spinning wheel map, the teacher did not challenge too much during the teaching gears topic (as illustrated in Figure 4.26). Map A includes five interactions and only KoIS acted as initiative components. However, all components interacted at least once as secondary interaction components. Furthermore, the topic "hoops" map (as seen in Figure 4.27) reflected the teacher knowledge on similar way with the maps of gears and spinning wheels.

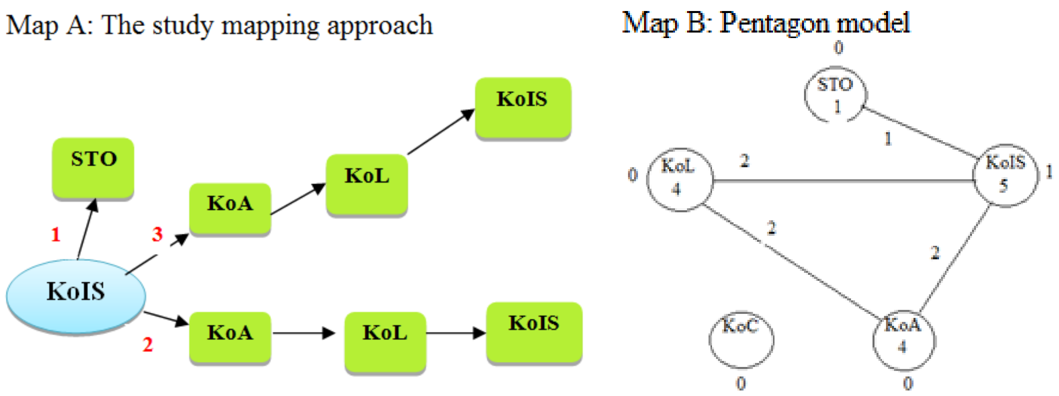


Figure 4.27. Teacher's PCK Map While Practicing Hoops

The friction force is the last topic of the unit force and motion. The topic had five objectives; Students will able to (a) demonstrate by experiment that the friction surfaces are getting warm, (b) realize that friction force leads to decrease on amount of kinetic energy, (c) explain the decrease of kinetic energy as an energy transformation, (d) generalize that air and water resistance lead to decrease on amount of kinetic energy, and (e) investigate where it is necessary to have more or less friction force. The objective (a) was covered by the students in fifth grade level. The objectives of (b) and (c) were discussed by the students in the topic "kinetic energy" and "conservation of energy". The objective (d) was explained by the teacher at the beginning of friction force topic and the objective (e) was not mentioned by the teacher. As a summary, the teacher asked some questions including the objectives above (this pedagogy was reflected in the interaction 1 as seen in Map A in Figure 4.28) and she explained all objectives briefly (it reflected in the interaction 2).

The teacher's main goal was to engage the students in laboratory work in order students to investigate the relationships between friction force and mass/ surface area of any objects. This enriched activity was shown in the third interaction. After laboratory work, the teacher explained the relationships in the enriched activity and assessed students' performance. The pedagogies were shown in the fourth and the fifth interaction in the third teaching segment.

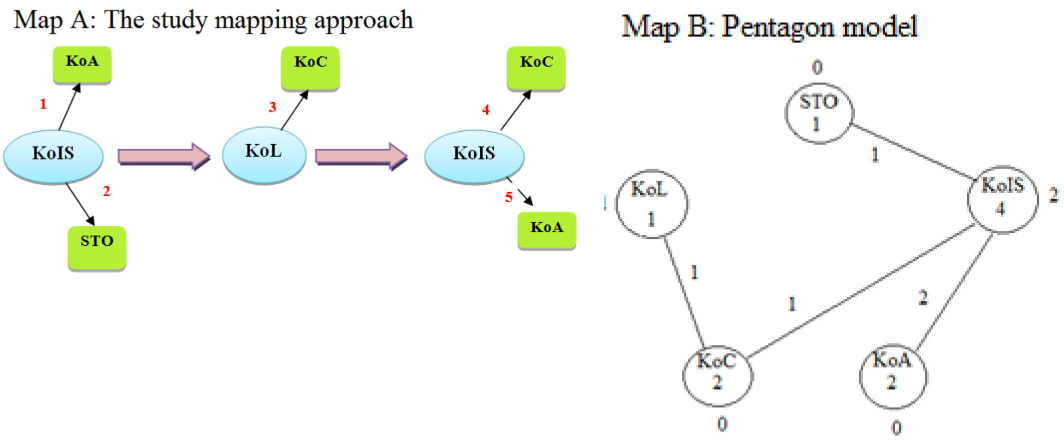


Figure 4.28. Teacher's PCK Maps While Practicing Friction Force

As always, KoIS and KoL were used as initiative components and all PCK components were used as secondary interaction component (except for KoL). Because the students involved in inductive laboratory work all class hour, the teacher only observed their performance, in other words, she did not involve in students' implementations. Thus, KoL included learning difficulties, and other sub-components did not appear during laboratory work.

As a general summary about interaction maps in the teaching practices, each PCK map has different characteristics because of nature of the topic including misconceptions, learning difficulties, or enriched concepts. Therefore, each map has different interactions. For example, the maps of pulley topic (Figure 4.22) have most number of interaction due to the fact that pulley includes more complex structure than other examples of simple machines such as hoists, gears. The differences between fixed and movable pulley, their formulas, and pulley weight led to some learning difficulties in the students' understanding. In order to deal with those difficulties, the teacher tried to explain by using different instructional strategies, examples, and demonstrations. Thus, the teacher's PCK interactions were most complex.

A similar situation is seen in kinetic energy and lever topics. The kinetic energy topic (Figure 4.17) has complex concepts leading to some learning difficulties. For example, although mass and speed affect the kinetic energy of an object, the students only considered affecting mass or speed. Thus, the teacher has challenged to explain the topic to them. Moreover, introducing the formula of kinetic energy also led to learning difficulties in terms of mathematical calculation, and enriched concepts. As a result, the teacher remedied those learning difficulties and used more different instructional strategies and techniques shaping the teacher PCK. Another more complex interaction map appeared in the lever topic where the teacher introduced the lever as the first example of simple machine. Teaching three kinds of lever, mechanical advantages, and formulas led to some learning difficulties. Dealing with each difficulty yielded more complex interactions in the map.

The topics of energy and simple machines have a main concept (energy and simple machine) and examples of their applications (kinetic energy, potential energy, and conservation of energy; lever, pulley, hoist, inclined plane, wheels, etc.). After teaching main concept, the first example of main concepts has more learning difficulties than following ones. The teacher had difficulties while teaching kinetic energy due to the fact that the students came across this topic for the first time. On the other hand, the potential energy led to less learning difficulties than kinetic energy because the students were able to transfer what they have learned about energy to the potential energy or next concepts. A similar transfer was seen in the simple machines. The students could transfer knowledge or skills about the features of simple machines to next examples of simple machines. Thus, the topic of inclined plane, spinning wheel, and gearing had less complex interactions than the lever or the pulleys.

According to the interaction maps, KoIS is center component for each PCK map and it interacted with each component in each map since the teacher engaged in instructional process by using varied kinds of presentation. Moreover, the teacher shaped her teaching based on KoL including prior knowledge, learning difficulties, characteristics of the gifted students, and alternative conceptions. As a result, in order to handle KoL requirements, the teacher selected appropriate instructional strategies or techniques. Thus, KoL shaped the teacher PCK components' interactions.

4.3.3 The Differences between the Interactions of PCK Components in Planning and Practicing Process

When the planning maps in Figure 4.12, 4.13, 4.14, and 4.15 were compared to the practicing maps in Figures from 4.16 to 4.28, the differences became clear. The first marked difference was related to the number of interactions. The teacher used more PCK components interactions in the planning stage related to the topics while she used fewer interactions in her actual teaching of those topics. The CoRe lesson plan allowed the teacher to think deeper and in detail during planning because she answered all of the CoRe questions and tried to take precautions against possible learning difficulties, and alternative conceptions. For example, while planning the kinetic energy, the teacher thought that there might be learning difficulties when introducing the formula of kinetic energy in terms of speed and velocity. She also predicted that some students might confuse the differences between speed and velocity, so it would take some class time even if she tried to explain the difference between two terms briefly. However, while teaching the formula of kinetic energy, there was no learning difficulty about the difference between speed and velocity. The students used the speed concept correctly. In this regard, learning difficulty related to the discrepancy between speed and velocity and dealing with appropriate strategies were not coded as PCK components' interactions in actual practice part whereas they were coded in planning part. Generally, in practicing the related topics, the teacher used her PCK components in order to explain targeted concepts, to assess conceptual understanding, to remedy alternative conceptions, and to reach her goals and purposes. In other words, KoIS, KoA, KoL, and STO generally interacted with another.

The second noticeable difference between planning and practicing is that each component interacted with others as an initiative component in the planning part, which meant that the teacher used some knowledge or ability as an initiative component in order to meet the pedagogical needs for meaningful learning. The initiative components the teacher deployed are also shown in Map A in Figure 4.12 and Figure 4.13 in large boxes. Thanks to the guidance by CoRe questions, the first main interaction component was STO which refers to the teacher's goals and purposes while teaching related topics. KoL followed STO to interplay with KoC in order to reflect gifted students' impact on the enrichment curriculum. Next, KoC interacted with other components in order to determine the objectives, materials, and enriched activities. After that, KoL which had the most interactions with others because the teacher considered the students' possible learning difficulties and alternative conceptions acted as a main component. Finally, STO interplayed with KoIS and KoA to choose appropriate instructional strategies and assessment techniques in order to reach her goal and purposes. While KoIS and KoA did not appear as initiative components in the planning stage, KoIS interacted with others as an initiative component in practicing maps because the teacher was in a facilitator role and her speech, demonstrations, explanations, questions, or guidance were suitable instructional strategies from the beginning to the end of each class. Moreover, KoL, KoC, or KoA sometimes acted as an initiative component in the practicing maps.

The last salient difference was related to the complexity of the interactions. Generally, binary or triple interactions were coded in the planning part. The teacher gave the answer to a CoRe question, and each question included binary interactions such as STO-KoC, KoL-KoIS, or KoL-KoA. Triple or multiple interactions rarely occurred in the learning difficulties part of the CoRe plans. For example, the interaction of KoL-KoA-KoIS aims at handling a misconception, and KoL-KoIS-KoA-KoIS-KoA-KoIS was coded so that if the students did not understand a concept, the teacher would apply different instructional strategies or techniques. On the other hand, in the practicing part, triple interactions of components generally occurred. When the teacher implemented her plan in class, many unexpected learning difficulties appeared and they were overcome by the teacher. Thus, the complexity of interactions increased towards the end of the course.

CHAPTER 5

CONCLUSION, DISCUSSION, & IMPLICATIONS

In this part of the study, the findings of the study were summarized first based on PCK components, and then each component results were compared and contrasted with the studies in the field of science teacher education.

5. 1 Conclusion and Discussion of the Findings for the Nature of Topic-Specific of PCK

5.1.1 Science Teaching Orientation

I discussed the teacher STO under three components in terms of Friedrichsen et al.'s (2011) view such as teacher' goals and purposes for science teaching, teachers view of science teaching and learning, and teachers view of nature of science.

The first component of STO is teacher goals and purposes for science teaching. The teacher had particular goals for science teaching and learning such as subject matter, schooling, affective, and gifted education. She gave priority to enhance the students' conceptual understanding of related subject matters as strictly following the curriculum objectives, and this goal is generally adopted belief among teachers (Ahtee & Johnston, 2006). She also did not concern schooling goals too much to prepare her students for TEOG (the passing examination to high school). Moreover, she also expressed some affective and gifted education goals because the school context is comprised of gifted students, and the students need to participate in differentiated educational supports (Renzulli, 1999; 2012; Sękowski & Łubianka, 2015). The second priority was to facilitate gifted students' interest in science, and to enhance her students' knowledge and special abilities. The teacher's goals about gifted education derived from school policy because the aim of the school was to determine gifted students' special abilities and to enhance those abilities by using appropriate educational opportunities. The aim is parallel with gifted students' education literature emphasizing that gifted students need to participate into additional educational opportunities rather than regular curriculum (Bangel et al., 2010; Croft, 2003; Çalıkoğlu & Kahveci, 2015). As conclusion, the teacher reflected multiple goals and purposes for science teaching and learning (Friedrichsen & Dana, 2005; Volkmann et al., 2005).

The second component of STO is teacher's views of science teaching and learning. The teacher presented her PCK in a teaching pattern for a science class, and the pattern included four parts; (1) Beginning of the lesson: the teacher reactivated or summarized the previous science concepts in order to determine the students' lack of knowledge, alternative conceptions, or prior knowledge. However, this pedagogy was not applied for all classes such as conservation of energy, simple machine, pulleys, inclined plane, gears and hoop. (2) Introduction of a new concept /engagement: in this part, the participant teacher utilized the questioning technique in order to help her students become ready for learning of new concepts, and to determine the students' alternative conceptions about new concepts. However, two distinctive classes, the teacher did not apply the questioning technique and she allowed her students to engage in an experiment aiming to discover the features of a related concept such as levers and friction force. (3) Presentation and elaboration of the target concepts: in this part, the teacher introduced or discussed the targeted concepts by using lecturing. (4) Evaluation: in this part, the teacher checked the students' performance after teaching.

As seen from above, the teacher presented varied and different instructional strategies and applications in her teaching pattern. Therefore, it seemed reasonable to not label the teacher's view of science teaching and learning on a specific orientation such as didactic, discovery, or inquiry because the teacher had multiple and complex STO (Friedrichsen & Dana, 2003; 2005), and her STO was in a messy structure (Abell, 2007) in teaching three physics topics. On the other hand, according to the results of card sorting activities, the teacher had a belief about science teaching and learning as student-centered orientation regarding of the teaching related physics topics, and she did not accept the didactic orientation as parallel her teaching. However, it was seen that the teacher also presented traditional teaching orientation in classroom teaching practices. In other words, there were some mismatches among the teacher's ideal beliefs (identified by card sorting activities) and working beliefs (identified during classroom teaching practice). This situation is generally common among science teachers' STO (Abell, 2007; Aydın et al., 2014; Campbell et al., 2017; Ekiz Kıran, 2016; Goodnough & Hung, 2009; Schneider & Plasman, 2011; Welch, Klopfer, Aikenhead, & Robinson, 1981). Because there are some factors such as exam based teaching (Aydın et al., 2014), loaded curriculum (Samuelowicz & Bain, 1992), lack of necessary time designing and applying minds-on activities (Friedrichsen & Dana, 2005; Jones & Carter, 2007) to affect teachers' STO. In this respect, the participant teacher explained the reasons of mismatches as follows; time concern requiring completing curriculum objectives in a limited time (it is a common reason in studies including Turkish science teachers (Aydın, 2012; Ekiz Kıran, 2016; Şen, 2014; Üner, 2016)), burden assigned by school management, lack of students' abilities such as inquiry skills. Therefore, the teacher preferred to apply lecturing in order to introduce new science concepts or to handle students' alternative conceptions during a limited time because lecturing was an easy way for the teacher to overcome unexpected events. Moreover, this result might be explained by Padilla and van Driel's (2011) work. The participant teachers as university professors in quantum chemistry believed that lecturing or didactic orientation is a more effective technique when making thorough and careful clarifications of specific concepts including abstract and complex in nature, or learning difficulties for students (Padilla & van Driel, 2011).

However, we cannot say that teacher had teacher-centered teaching orientation because she designed two inductive laboratory approaches and allowed the students to discover related science concepts. She also had planned a few additional student-centered activities but the limited time did not allow the teacher to put laboratory works into practice due to fact that the students-centered or inquiry activities require to have enough time both designing and enacting of them (Tamir, 1988; Welch et al., 1981). Moreover, because of characteristics of gifted students arising from this study such as interrogating and questioning of new information (Stott & Hobden, 2016), asking challenged, unusual, and insightful questions (Miller, 2009; Park & Oliver, 2009), and boring during the lecturing parts of teaching (Joffe, 2001; Park & Oliver, 2009; Samardzija & Peterson, 2015), they enabled to change the direction of teaching from teacher-centered to student-centered. Furthermore, the teacher enriched her lectures by utilizing power point presentation, demonstrations, models, examples and questions in order for students to be active participants. Especially, the discussion technique is more appropriate in order to make the gifted students be active participant (Coleman, 2003).

As a result, we cannot label the teacher' STO in which she had a didactic orientation explained by Magnusson et al. (1999) which is about convey the SMK to the students. Moreover, the teacher had multiple orientations, which is supported by the literature as science teachers might reflect varied kinds of teaching patterns (Abell, 2007; Friedrichsen & Dana, 2003; 2005).

The third component of STO is teacher's view of the nature of science. In the study, the teacher neither planned nor practiced any teaching behavior about nature of science aspects, and she also did not select the scenario about history of development of concepts. In other words, the aspects of nature of science were not considered to enhance students understanding of science abilities. This situation is common among science teachers (Aydın et al., 2014; Boesdorfer & Lorsbach, 2014; Demirdöğen, 2016; Ekiz Kıran, 2016; Schneider & Plasman, 2011; Şen, 2014). Although teachers ignore the teaching and learning of nature of science aspects, the gifted students need much more nature of science aspects to gain scientific intuition. As a result, whoever has a special ability in science have to know philosophy of the nature of science (Gilbert & Newberry, 2007).

To sum up, the teacher reflected STO which is complex and subject specific. In order to analyze whether the participant' STO is topic-specific or subject specific; I designed and applied individual card-sorting activities for each topic. According to the card-sorting activities, the teacher grouped and reflected similar scenarios over the three topics including work and energy, simple machines, and friction force. One difference was seen in the topic work and energy, and the teacher did not select academic rigor scenario for gifted students. However, the rest of two topics such as simple machines and friction force, the teacher believed that academic rigor activities including simple machines problems and challenged examples help to enhance the students' problem solving and critical thinking ability, and the challenges help the students enhance future learning of the mechanical issues. Therefore, if academic rigor scenario is excluded, the participant teacher reflected similar results during each activity, and it can be said that the teacher STO is subject specific in nature. This finding is consistent with previous studies (e.g., Abell, 2007; Aydın et al., 2014; Friedrichsen & Dana, 2005). However, Campbell et al.'s (2017) work showed that teacher's STO was topic-specific, and it was affected different resources such as activities or topics. Their participant teacher selected standard-based reform orientation; however, the participant reflected different degree of reform level which was changing from topic to topic. For instance, the teacher reflected more traditional orientation in the oceanography topic whereas the pollution topic was presented in more reform-based orientation.

One specific aspect of STO component was seen in the results of being gifted students in classroom context. The teacher' STO was affected by gifted students in terms of goals and purposes of science teaching, and teacher views of science teaching and learning. Gifted students shaped the teacher goals and purposes by adding additional goals such as determining gifted students' special abilities, and enhancing those abilities by utilizing specific educational activities such as enrichment activities. As illustrated this effect of gifted students on the teacher's goals from teaching kinetic and potential energy topics, the gifted students asked more concreate examples and explanations from the teacher. This request led the teacher to design and apply enrichment activities including mathematical calculation requiring using the formula of kinetic and potential energies. After getting feedbacks about students' performance, the teacher stated her reflection in the post-interview of kinetic and potential energy as she decided to add more and challenged problems related to kinetic and potential energy to her plan for the next year.

Moreover, the teacher' view of science teaching and learning was shaped by the gifted students, which the teacher' STO changed from teacher-centered to student-centered orientation, because traditional strategies are not enough to meet the needs of gifted students (Winstanley, 2007). The most distinctive example was seen while teaching pulleys topics. The teacher planned to introduce pulleys by using lecturing, but when she explained the differences between fixed and movable pulleys, there was confusion in students' mind. Some of them did not accept fixed pulley as a simple machine, and one student did not understand the meaning of the mechanical advantages in the movable pulleys. In other words, the lecturing was not enough for better understanding, and the teacher tried to present alternative ways such as demonstrations, videos, and pictures. However, the students were not satisfied by the alternatives. Finally, she decided to engage the students in hands on activity in which the students measured the weight of some specific objects by using dynamometer in practicing fixed and moveable pulley respectively. As a conclusion, the characteristics of gifted student shaped the teacher teaching from lecturing to hands-on activity, and this result is parallel with Park and Oliver's (2008) work, in which teachers' STO were affected by gifted students in terms of goals and purposes of science teaching and teachers' views of science teaching and learning.

On the other hand, STO component shapes the other PCK components and teacher teaching (Abell, 2007), and it is seen as the overarching component (Boesdorfer & Lorsbach, 2014; Grossman, 1990; Magnusson et al., 1999) and teachers teaching and applications (Abell, 2007). Although STO affect and shape other knowledge bases and components, it is also affected by some factors such as the out of school activities (Friedrichsen & Dana, 2005), school context (Friedrichsen & Dana, 2005; Ramnarain & Schuster, 2014). In some context, STO might act as a filter to act as an obstacle other PCK components (Friedrichsen et al., 2009; Friedrichsen et al., 2011). Moreover, contextual factors such as time concern (Friedrichsen & Dana, 2005), large class size, inadequate materials and resources, (Ramnarain & Schuster, 2014), or exam based teaching and learning (Nargund-Joshi, Park, Rogers & Akerson, 2011) have negative affect on teachers STO during applying students-centered or reform based activities. However, in this study, the participant teacher's STO was affected by school context including gifted students who shaped the teacher's teaching from traditional orientation to student-centered orientation.

Contrary to science teacher PCK literature, Gess-Newsome (2015) and her colleagues removed STO from PCK category and explained the teachers STO in "amplifiers and filters" category. They believe that "amplifiers and filters" has an effect on teacher teaching, in other words, teachers beliefs, orientations, and prior experience act as amplifier or filter during teachers' decision making process and teaching practices (Gess-Newsome, 2015). In Melo et al.'s (2017) study, the effects of emotions acted as amplifiers and filters in both teachers' decision making process and practicing. In other words, the negative emotions (frustration and anxiety related to mathematical challenges to use for physics acted as filters) or positive emotions (satisfaction, capability, security, and confidence deriving from the teacher's content knowledge, and her successful application of lab work and experimental activity acted as amplifiers) shaped the teachers' PCK similar to the beliefs in STO. As a conclusion, the characteristics of gifted students and their learning behaviors acted as amplifiers during both the teacher planning and the teacher practicing related concepts.

5.1.2 Knowledge of the Curriculum

The teacher utilized the science curriculum very effectively when she selected objectives, activities, or materials because her first goal was to provide the students with conceptual understanding. In other words, she followed closely the curriculum to plan and apply related topics and activities. However, following curriculum strictly refers to novice teacher behaviors who feel incompetent themselves on designing and applying any teaching because the teachers have weak knowledge about science curriculum including science ideas or resources when their initial teaching experience is considered (Schneider & Plasman, 2011). However, the participant teacher could alter the sequence of the sub-topics, and she redesigned the sequence of the sub-topics such as lever, pulleys, hoists, inclined plane, spinning wheel, gears and hoops in order to help students gain better understanding. In doing so, the teacher used the time more efficiently because effective teachers require to able to distinguish the differences between main concepts and trivial concepts for students' future learning (Geddis et al., 1999).

Training or certification programs designed to enhance teachers' KoC provide the teachers with obtaining much more science standards (Friedrichsen et al., 2009), and the scope and sequence of concepts (Park & Oliver, 2008). In this respect, the participant teacher did not engage in specific training program until this study. However, Ministry of National Education (2006) has offered the teachers science curriculum as guidance. The science curriculum from 5^{th} to 8^{th} grades included objectives, classroom and outside activities, limitations, students' alternative conceptions, timeline (schedule), teaching methods and strategies, and assessment techniques. Therefore, this detailed guidance enabled the teacher effectively to design related activities or classes by utilizing her knowledge about vertical and horizontal relationships among science concepts (Aydın et al., 2014; Şen, 2014).

According to the science curriculum (MNE, 2006) in Turkish context, teachers can reach all knowledge and materials about both each subject (physics, chemistry, biology, etc.) and each topic (work and energy, simple machines, friction force, etc.). Moreover, each topic or science concept has different characteristics such as objectives, recommended activities, limitations, students' alternative conceptions, or instructional and assessment strategies. In this respect, it is assumed if a teacher is able to design and practice science lesson for any science topic by using science curriculum from 5^{th} to 8^{th} grades effectively; the teacher has strong knowledge of curriculum. Moreover, the participant teacher's KoC can be also considered topic-specific in nature. This result is also supported by Aydın et al.'s (2014) study, however, Shulman (1986) and Gess-Newsome (2015) take consideration of KoC as a knowledge base and it is subject-specific in their models.

In addition to science curriculum content (MNE, 2006), teachers enhance their KoC while they are teaching and learning from one topic to another. In doing so, they discover or recognize that each topic has different goals, outcomes, and alternative resources (Goodnough & Hung, 2009). This situation is also supported by Schneider and Plasman's (2011) findings. They found that pre-service or novice teachers did not reflect their KoC more effectively than experience teachers because new teachers were unfamiliar with scope, sequence, standards, or material in a curriculum. Therefore, it is expected that each science topic provides teachers with valuable planning and teaching experience.

Another salient knowledge appeared while the teacher was designing enrichment activities. Due to the characteristics of gifted students, they need to engage in enrichment curriculum materials (Çalıkoğlu & Kahveci, 2015; Gilman, 2008). The teacher first aimed to teach the conceptual understanding of related topics by utilizing textbook objectives and materials, and then, the students were able to learn related concepts easily and quickly. In doing so, the rest of time, the teacher provided her students with detailed and advanced knowledge and application by using upper class concepts, or activities, which was called enrichment activities (Freeman, 1998; Kim, 2016; Thomson, 2006). While designing enriched activities, the teacher had to investigate both secondary science curriculum objectives, materials and her students' prior knowledge and skills that the students need to use them during activities. This enrichment process distinguished the teacher from the category in which novice or intern teachers consider curriculum with the textbook or follow the curriculum strictly (Friedrichsen et al., 2009). In other words, determination of gifted students' needs is a teacher competency (Croft, 2003), and in order to handle their needs including designing and enacting any science enrichment activities require the teacher to use different competencies and skills (Chan, 2001; Croft, 2003; Fiddyment, 2014; Johnsen et al., 2002; Park & Oliver, 2009; Pfeiffer & Shaughnessy, 2015; Shaughnessy & Sak, 2015). Therefore, designing and applying enriched activities in this study might enhance the teacher' knowledge both enrichment curriculum and regular curriculum.

The teacher provided the gifted students with enrichment activities including high school curriculum concepts and objectives, and activities. In doing so, the students gained more content knowledge rather than skills including science process skills, nature of science, or creative and productive skills. In the literature, using upper concepts and material to design enrichment activities including more detailed and advance conceptual understanding is discussed by some researchers (Renzulli, 2012; Shaughnessy & Sak, 2015). It is agreed that the gifted students need to more challenging content to enhance their special abilities (Çalıkoğlu & Kahveci, 2015; Newman & Hubner, 2012; Shaughnessy & Sak, 2015) but only knowledge is not enough for gifted students to enhance these abilities (Renzulli, 2012). In addition to content knowledge, they need to engage in specific activities helping them enhance science process skills (Çalıkoğlu & Kahveci, 2015), nature of science (Gilbert & Newberry, 2007), critical and creative thinking skills, and 21st century skills (Kaplan, 2012), and their motivation toward science (Çalıkoğlu & Kahveci, 2015; Newman & Hubner, 2012). As a conclusion, there are three aims to educate the gifted students; (1) in order to enhance maximum cognitive development and self-fulfillment (2) to generate talented people reservoir in order to provide society with specific benefit arising from scientist, artists, engineers or leaders (Mammadov, 2015; Renzulli, 1999). (3) The last aim is to generate creative and productive individuals (Aljughaiman & Ayoub, 2012; Renzulli, 2012). By taking into consideration above literature, the gifted students should be engaged in the development of productive and creative process (Renzulli, 2012). The gifted students can reach their fulfillment level on creative and productive skills if they participate in activities designed in the level of proximal development zone (Vygotsky, 1978). In this zone, gifted students can both realize their special abilities and enhance those abilities. Moreover, true and real development of abilities appears in this zone through helping gifted students reach new competencies (Taber, 2007).

5.1.3 Knowledge of Learner

This part of discussion section includes four subtitles in this study; (1) knowledge of the characteristics of gifted students, (2) knowledge of requirements for learning, (3) knowledge of areas of student's difficulty, and (4) knowledge of areas of student's alternative conceptions.

Knowledge of Characteristics of Gifted Students: This part includes the teachers' opinions about the gifted students' special educational behaviors observed during the teacher's teaching such as quick and easy learning related to science concepts, asking difficult and interesting questions, and extending enriched activities and discussions. To summarize the characteristics of gifted students arising from this study; (1) the gifted students were not easily persuaded while learning new concepts and they did not easily accept. (2) The gifted students tended to participate in discussion with the teacher and their friends so this characteristic led to waste of class time, but discussion instructional strategy is more appropriate for gifted learners so as to enhance their critical thinking skills (Coleman, 2014). (3) The gifted students tended to ask difficult and interesting questions. (4) The gifted students tended to set impossible aims where they tried to conduct experiment impossible to be done in the classroom. (5) The gifted students could extend the enriched activities by their interrogation and questions, and the teacher had to explain or introduce more upper science concepts or facts. (6) The last but the most common characteristic of gifted students was that the students could learn quickly and easily any science topics and concepts. In this respect, all the characteristics were observed in this study, and each of them affected the teacher teaching while practicing work and energy, simple machines, and friction force.

The participant teacher knew her students closely and gave individual attention each of their learning, to illustrate; she monitored her students' assignment and performance until the completion period. She was also aware of a characteristic of their students that gifted students generally modified new knowledge and compared it with their preexisting knowledge, and then, they can apply it to new situation. In doing so, the teacher was able to modify the sub-topic sequence in the curriculum in order to help students transfer preexisting knowledge into new situations. Therefore, she faced less pedagogical difficulties during the teaching of spinning wheel and hoists topic. Moreover, her students persisted to interrogate scientific phenomena and the teacher explanations, and the teacher did not pass to teach next topic until they obtained meaningful learning (Stott & Hobden, 2016). To sum up, the characteristics of gifted students observed in this study were aligned with the gifted students' literature, to illustrate, they are not easily persuaded when they learn new concepts (Stott & Hobden, 2016), they tend to ask difficult and interesting questions (Miller, 2009; Park & Oliver, 2009), they could extend the enriched activities by their interrogation and questions (Laine, Kuusisto, & Tirri, 2016; Stott & Hobden, 2016), they could learn quickly and easily any science topics and concepts (Gilman, 2008; Joffe, 2001; Laine et al., 2016; Manning, 2006; Miller, 2009; Park & Oliver, 2009; Taber, 2007).

The development of PCK arises from two resources such as content knowledge and students' knowledge (Shulman, 1987; Veal et al., 1999). In the present study, the participant teacher might enhance her content knowledge through designing and implementing various kinds of enrichment activities, and her PCK and especially KoL might be also enhanced by the gifted students and their characteristics (Park & Oliver, 2008). To sum up, the school context including gifted students acted as amplifier in order to development of her PCK (Gess-Newsome, 2015) due to the fact that the gifted students provided the teacher with development some specific abilities such as understanding characteristics of gifted students, and designing and implementing of enrichment activities which are unusual and non-generalizable abilities to better understand the teacher PCK (Baxter & Lederman, 1999).

Knowledge of Requirements for Learning: The knowledge about students' pre-requisite for learning means to teachers need to having knowledge and abilities for students' meaningful learning. In other words, students have varied kinds of requirements such as learning style, prior knowledge or abilities, or different learning level. Therefore, teachers should be aware of these differences while designing and implementing related science topics (Magnusson et al., 1999). In this respect, the teacher in the present study was aware of these requirements for meaningful learning in terms of conceptual understanding. Due to her KoC, she could consider sequences of concepts in curriculum and she could also assess the students' prior knowledge about those concepts at the beginning of each class. To illustrate, in order to provide meaningful understanding for work and energy topic, the students should have knowledge about following concepts; force, net force, reluctant force, and work (to understand energy and its types). Another example is that the understanding of the concept of simple machines and its aspects plays an important role in the understanding of other concepts that follow (Marulcu & Barnett, 2013).

In this respect, these requirements were considered by the teacher during the planning process but the teacher discovered some additional pre-requirement concepts student should have during teaching parts such as differences between mass and gravity, and unit of force and gravity. Moreover, the students needed to have some abilities to participate laboratory work such as using dynamometer and measuring force. The teacher recognized these requirements during the teaching of related concepts, in other words, this pedagogical development is evidence that the professional development of teachers is enhanced by teaching experiences (Abell, 2007; Goodnough & Hung, 2009; Lee & Luft, 2008; Magnusson et al., 1999; Park & Oliver, 2008; Schneider & Plasman, 2011; Şen, 2014). On the other hand, the mathematical calculations were a concern (in some cases, it is considered as a negative emotion (Melo et al., 2017)) for the teacher during enriched activities owing to fact that the teacher designed the activities including formula necessary for students to have mathematical calculation skills.

Knowledge of Areas of Student's Difficulty: As a common view, science concepts are abstract and complex in nature so it is difficult to learn for students and to teach for teachers (Ginn & Waters, 1995; Loughran et al., 2006). As regarding physics concept more specifically, teachers consider that teaching physics concepts more difficult than other subjects (Ahtee & Johnston, 2006; Johnston & Ahtee, 2006). These negative opinions about science concepts lead to hinder the development of teachers PCK (Geddis & Wood, 1997).

With this in mind, the participant teacher believed that her students had negative attitude toward force and motion units through 5^{th} to 8^{th} grade. Therefore, while teaching related concepts, the teacher faced many learning difficulties. The verbal explanation of the teacher was not enough for students to meaningful understanding because of abstract nature of concepts, and physics concepts are not easily explained (Johnston & Ahtee, 2006). The teacher had to involve additional attempts and efforts such as explaining formula of phenomena in order abstract nature to become more concrete nature as numerical evidence. To sum up, contrary to Geddis and Wood's (1997) opinion about negative attitude hinder the development of PCK, the participant teacher might enhance her KoL and KoIS while she was handling each of learning difficulty.

The teacher's knowledge of areas of student difficulty arose from two resources such as students' pre-requisite knowledge and enrichment activities including upper concepts and materials. The first resource was generated by the nature of physics concepts including abstract and complex phenomena, and the students had difficulties for understanding each of them. The second resource was related to enrichment curriculum materials requiring the students should have additional background knowledge and abilities. As a conclusion, each enriched activity caused learning difficulties in teaching of the related topics, and the teacher had valuable experience from feedback of students' performance. Therefore, it is important being aware of students learning difficulties for the teachers but many studies have not been considered students' learning difficulties as a sub-component, stated differently, they have only focused on students' misconceptions, how the misconceptions are determined and how they are handled (Schneider & Plasman, 2011).

Knowledge of Areas of Student's Alternative Conceptions: The teachers and students have misconceptions or alternative conception about physics concepts such as work and energy (Avcı, Kara, & Karaca, 2012; Çoban, Aktamış, & Ergin, 2007; Kruger, 1990; Trumper, 1998; Yürümezoğlu, Ayaz, & Çökelez, 2009), simple machines (Marulcu & Barnett, 2013), and friction force and energy (Atasoy & Akdeniz, 2007; Hançer, 2007; Hope & Townsend, 1983; Kaplan, Yılmazlar, & Çorapçıgil, 2014) because of the abstract and complex nature of them. The present study has three topics such as work and energy, simple machines and friction force. Naturally, alternative conceptions arising from students' thoughts appeared while the teacher was teaching each topic. In this respect, the alternative conceptions of students were separated by two categories such as awareness of the teacher, and unawareness of the teacher. In the awareness category, the teacher stated the possible alternative conceptions in her CoRe lesson plans, such as (1) work is anything someone does in daily life, (2) speed and velocity are the same things, and (3) machine is something which includes technological elements. These alternative conceptions are considered in literature as misconceptions, and the teacher was conscious all of them. Therefore, she took specific precautions to determine and handle each of them before teaching related concepts.

However, in the unawareness category, the teacher discovered some alternative conceptions arising from students' daily life, their experiences, or reading upper grade resources while she was teaching related topics. To illustrate, (1) a fast car has more kinetic energy than a slow car, (2) an object which is at the higher position has more potential energy than the one is at a lower position, (3) energy is lost when it changes from kinetic to potential, (4) stairs are not an inclined plane because we cannot transport any object along the stairs by dragging, (5) mass and weight are the same things, (6) we can obtain mechanical advantages from work and energy, and (7) friction force is always in the opposite direction to the object's motion. Therefore, she could not take specific precautions to determine and handle each of them. All these alternative conceptions led to more learning difficulties while the teacher was overcoming each of them.

While the teacher was determining the possible alternative conceptions, the questioning strategy was used at the beginning of the lessons, to create a brief discussion. Moreover, the students' responses and their performance in the activities helped the teacher recognize alternative conceptions in the unawareness category. After teaching related topics, each alternative conception in the unawareness category was discussed with the teacher in the post-interviews. The teacher confirmed each alternative conception arisen from her teaching practices, and which caused the learning difficulties. However, I did not clarify whether or not the teacher was familiar with those alternative conceptions in the unawareness category. She might have known those alternative conceptions but she may not have mentioned her CoRe plans, or she might have been unaware all of them and she could not write her plans. There was a certain thing that the alternative conceptions in the unawareness category were arisen from classroom practices. To sum up, if the teacher was unaware of those conceptions, it could be said that the teacher did not have enough knowledge about students' alternative conceptions. Similar result also appeared in Friedrichsen et al.'s (2009) study in which the participant teachers were unfamiliar with topic-specific alternative conceptions. She did not also use additional strategies to overcome these alternative conceptions such as concept map, models, analogies or KWL chart, which is also similar to Ekiz Kıran's (2016) results. Therefore, the teacher did not reflect rich PCK about how alternative conceptions were determined and how they were overcome. However, the teacher might enhance her PCK by discovering the alternative conceptions in the unawareness category because teachers' knowledge about students' alternative conceptions acts as a primary resource which affects the teachers PCK (Park & Oliver, 2008).

To sum up, the teaching experiences of three topics work and energy, simple machines, and friction force enhanced the teacher' KoL through facing unusual and non-generalized students' interactions (Goodnough & Hung, 2009) due to the fact that KoL is topic specific in nature, in other words, a teacher can present different knowledge level from one topic to another (Aydın et al., 2014). This experience also increased the teacher SMK through designing and implementing enrichment activities, and her students' challenging questions because novice teacher or pre-service teachers do not have enough knowledge about both SMK and KoL. They consider the teaching as a transformation SMK to the learners, stated differently; they ignore the knowledge of students about science and only focus on SMK. However, "teacher thinking appears to progress first to thinking about learners, then to thinking about teaching, and finally to building a repertoire" (Schneider & Plasman, 2011, p. 555).

5.1.4 Knowledge of Instructional Strategies

As usage of instructional strategies and presentations in work and energy, simple machines, and friction force, the participant teacher utilized different strategies based on the nature of the topics. On the other hand, subject-specific instructional strategies such as inquiry, learning cycle, or conceptual change approach were not practiced though teaching of three physics topics. Actually, this situation is not really surprising in Turkish context (Akın, 2017; Aydın, 2012; Ekiz Kıran, 2016; Şen, 2014). There might be some reasons why the teacher did not tend to consider subject-specific strategies such as teacher beliefs (Magnusson et al., 1999). The decision making process might hinder the selection of subject specific strategies and some factors might act as filter to shape the teacher teaching or decision making process (Gess-Newsome, 2015) such as lack of time (Friedrichsen et al., 2011), loaded curriculum (Ekiz Kıran, 2016; Samuelowicz & Bain, 1992), lack of knowledge and ability about implementation of strategies (Settlage, 2000; Welch et al., 1981), or lack of teaching experience (Flick, 1996). In addition to filters, professional development might affect the reluctance of subject-specific strategies. The participant teacher had engaged in the experience of argumentation method for gifted students training program, and she believed that she had enough knowledge and abilities to designing and implementing of argumentation. In doing so, she tried to apply argumentation activities but she did not achieve. The reasons why the teacher was unsuccessful arisen from limited time, lack of teaching experience, and lack of the students' knowledge and abilities to conduct the argumentation.

As regarding work and energy topic, the teacher started the lesson with questioning technique to determine the students' prior knowledge and alternative conceptions. This step was very important for the teacher because students' prior knowledge about work and energy shaped the meaningful learning of targeted concepts. If any alternative conceptions or incorrect prior knowledge were detected, the lecturing or verbal explanations were utilized to overcome the incorrect information because the teacher believed that verbal explanation is more appropriate precautions in the limited time. After practicing the questioning technique, the teacher practiced the targeted concepts by lecturing which was enriched with power-point presentations, demonstrations, discussions, or models. The usage of topic-specific instructional strategies varied from sub-topics to sub-topics and students' feedback. This effect of students' feedback on teachers' teachings appeared in Lee and Luft (2008) work in which teachers redesigned and modified their teaching based on students' performance.

In the present study, this lecturing part was slightly different from general meaning due to the fact that gifted students tend to participate in lecturing parts of lesson by using discussion questions. Stated differently, in the lecturing part; the gifted students were active participants by their questions. In the literature the studies (Miller, 2009; Newman & Huber, 2012; Park & Oliver, 2009) support this result as gifted students are active participants and they tend to create discussion environment (Coleman, 2014) because they are bored in the teacher-centered instruction (Samardzija & Peterson, 2015). Therefore, the students do not accept the teacher's verbal explanations easily (Stott & Hobden, 2016), so they ask more concrete examples. In this respect, the participant teacher faced the effects of characteristics of gifted students in this present study. For example, her students asked more concrete explanations or examples and in order to handle this situation, the teacher offered the formula of related science phenomena, and gave some numerical problems. After all, the students took note about important definition, facts, or formulas and examples. The teacher used generally same teaching pattern including questioning, lecturing, teacher application of specific problems, and then evaluation of students' performance. This teaching pattern might be arisen from the teacher's learning experienced during her high school or undergraduate years (Grossman, 1990). Moreover, the lack of knowledge about subject-specific instructional strategies or the lack of their experiences might be a reason why same teaching pattern was utilized by the participant teacher (Aydın, 2012). On the other hand, the teacher tried to engage her students in argumentation teaching method for learning of kinetic and potential energy. However, the students did not achieve to complete argumentation because of some limitations such as insufficient time and shortage of materials, and lack of the students' argumentation skills.

As regarding instructional strategies for simple machines, the similar topic-specific instructional strategies were observed in the teaching of sub-topics, but some specific differences appeared such as inductive laboratory work, advanced and complex problems aligned with the academic rigor STO, analogy among levers and spinning wheel, and model of gears and hoops. The first example of simple machines was levers and the students engaged in inductive laboratory work in order to discover mechanical advantages of force and load. At the end of the lab work, the students were successful on the meaningful learning of levers. After teaching lever topic, the teacher utilized the similar topic-specific instructional strategies and teaching pattern while teaching other example of simple machines such as pulleys, hoists, inclined plane, spinning wheel, and gears and hoops. Moreover, a difference application appeared while teaching pulleys and hoists sub-topics. Advanced and complex problems including secondary science curriculum objectives and applications were employed by the teacher in order the gifted students to participate in challenging problems to enhance their special abilities. Another different instructional strategy occurred during the introduction of spinning wheel sub-topic. The teacher utilized the analogy method so as the students to transfer previous learning of mechanical advantages of lever to spinning wheel topic. The gifted students were very successful in transforming of preexisting knowledge and applications to new situations. Stott and Hobden (2016) identified this learning strategy as *linking and organizing* where gifted students modify or change the previous knowledge in order to connect it with new situations. The last different strategy was to use the model including some gears and hoops connected together with parallels, cross, and chained in order the students to gain firsthand experience with gears and hoops.

As regarding the last topic of friction force, the teacher employed the similar topic-specific strategies with work and energy. However, a different strategy appeared at the end of the topic as called inductive laboratory work which including similar pattern with lever topic. In the laboratory work, the students discovered the relationships between the friction force and the surface/weight of any object.

One salient feature of the teacher was to offer her students mathematical calculations and formula after introduction of targeted science concept or phenomena. The reason why the teacher used mathematical calculation was to present the gifted students more concrete evidence because of the abstract and complex nature of physics topics (Ahtee & Johnston, 2006; Ginn & Waters, 1995; Johnston & Ahtee, 2006; Loughran et al., 2006). In this respect, the gifted student generally negotiated and questioned all explanations mentioned by the teacher and they did not accept the teacher explanation easily. Thus they need to see more concrete examples or explanations. So as to handle this situation, the teacher selected to support her explanations with numerical evidence, and formula of science phenomena. Another reason why the teacher used mathematical calculation was to engage her students in more challenging topics and applications because gifted students need to participate in challenged and advanced learning environment so as to enhance their abilities (Croft, 2003; Manning, 2006; Sękowski & Łubianka, 2015). In this respect, simple machines and its examples were more appropriate enrichment activities for gifted students. The last reason why the teacher used mathematical calculation was to prepare her student for high school context. The enrichment activities including secondary school science curriculum objectives and materials in terms of the topics of work and energy, simple machines, and friction force provided her students with valuable experience in which the student practiced the mathematical problems. Therefore, the teacher believed that her students would become familiar with secondary school topics by participating in the enrichment activities. On the other hand, teachers generally present mathematical problems and formula in secondary school level students and exam-based context (Aydın, 2012; Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008; Üner, 2016). Stated differently, teachers who have exam-based orientation take place multiple choice, open-ended problems including the using a formula in their teaching.

5.1.5 Knowledge of Assessment

Before summarizing the participant teacher's KoA, it is important to emphasize the notion of KoA in science teacher literature. In general meaning, KoA has been ignored in PCK studies (Abell, 2007; Schneider & Plasman, 2011). Although some studies investigated KoA, participant teachers focused much less consideration on assessment process both planning and practicing related topics than other PCK components (Padilla & Driel, 2011; Schneider & Plasman, 2011). Even more, Friedrichsen et al. (2009) found that both interns and experience teachers did not include assessment part in their lesson plan, and they only used informal strategies to monitor students' performances. Moreover, some studies investigated the interaction of teachers PCK components, and they had common result that KoA was connected with other components at least level (Aydın & Boz, 2013; Aydın et al., 2015; Kaya, 2009; Padilla & Driel, 2011). As a conclusion, teachers do not pay enough attention or do not consider utilizing assessment process in their teaching. Friedrichsen et al. (2009) interpreted this deficiency of KoA that teachers having teacher-centered orientation consider assessment as summative in nature including multiple choice tests, or quizzes performed at the end of the related unit. Those teachers use only informal techniques such as questioning or monitoring students' performance, thus, they did not take place the assessment in their lesson plans.

By taking into account the teacher's knowledge of assessment in this study, she could check the students' prior knowledge, alternative conceptions, and performance through at the beginning to the end of class because she monitored the students' conceptual understanding very closely, namely, the individual evaluation was utilized. She was also aware of the assessment role to shape her teaching in terms of curriculum and instructions by getting students feedback. In doing so, individual assessment in which the teacher determined her students' prior knowledge, skills, and deficient parts of topic played essential role in order to provide meaningful understanding while designing and implementing enrichment activities.

The teacher generally focused on students' conceptual understanding on the topics of work and energy, simple machines, and friction force. Therefore, she presented the assessment pattern during her teaching; to elicit student's prior knowledge or alternative conceptions, content assessment, and to grade students' performance. The teacher also utilized informal assessment techniques such as questioning and observation which are commonly utilized among by the teachers (Ekiz Kıran, 2016; Friedrichsen et al., 2009; Schneider & Plasman, 2011; Şen, 2014; Üner, 2016) to elicit student's prior knowledge whereas she used formal techniques such as quizzes, test, or homework to assess conceptual understanding or students' performance on targeted concepts.

To sum up, the teacher performed the similar assessment pattern and techniques in order to evaluate her students' performance during the three physics topics. Therefore, it can be said that KoA acts as subject specific in nature (Aydın et al., 2014; Üner, 2016). This result is aligned with Gess-Newsome (2015) PCK model in which assessment knowledge is considered as a knowledge base in subject-specific nature. The reason why the teacher performed the similar assessment pattern might be arising from her KoL (Henze et al., 2008). In this study, the teacher had some deficient alternative conceptions about physics topics, and if she was more aware of them, it is reasonable to think that she would vary her teaching and assessments. Moreover, the development of teachers KoA enhances more slowly than other components (Hanuscin, Lee, & Akerson, 2011; Henze et al., 2008), thus, teachers require participating in professional development programs in order to enhance their assessment repertoires because teachers' inadequacy on authentic assessment techniques lead them to choice traditional assessment strategies (Aydın, 2012; Goodnough & Hung, 2009). An example of professional development process, Falk (2012) designed a formative assessment context for teachers' professional development in order to enhance teachers' knowledge and practices. During the training program, participant teachers generally used KoC, KoIS, and KoL. At the end of program, teachers enhanced their KoL, KoC, and KoA. As a conclusion, KoA in terms of formative knowledge and abilities was only enhanced through teachers' evaluating and reviewing assessment tasks in the professional development programs. Otherwise, teachers generally use knowledge of assessment strategies which are shaped and arising from the notions of teachers' student years (Kamen, 1996).

5. 2 Conclusion and Discussion of the Interaction PCK Components

In this part of the study, the interaction PCK components both planning and practicing parts were first summarized and then discussed with the interaction PCK literature.

In order to summarize the teacher's PCK maps for planning process, Figure 5.1 can be constructed. The three components of STO, KoC, and KoL acted initiative components in the planning process due to the fact that the CoRe lesson plans and pre-interviews questions shaped the teacher's decision making process. At the beginning of her plans, the teacher reflected her goals and purposes to select curriculum objectives, enrichment activities, instructional strategies, and assessment techniques. Then, she planned to design enrichment activities in order to meet the needs of gifted students. In this part, KoC played important role to combine the students' prior knowledge and the teacher knowledge about high school curriculum. Finally, the teacher considered the students' possible misconceptions and learning difficulties while planning all topics. In the planning part, the three PCK components were often interacted by the teacher with her other PCK components.

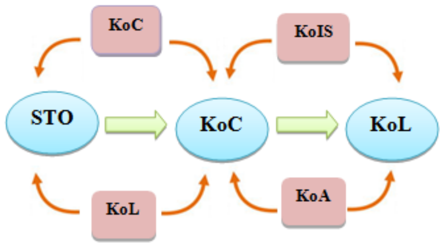


Figure 5.1. The Summary of the Teacher's PCK Components Interactions in Planning Stage.

KoL and KoC shaped the teacher goals and purposes as seen in Figure 5.1. When looking at the data arising from CoRe plan and pre-interviews in detail, the sub-components of knowledge of characteristics of gifted students in KoL and knowledge of enrichment curriculum in KoC affected the teacher decision making process. Because her learners were gifted students, they needed to engage in enrichment activities. Thus, she had to differentiate her STO from general science teachers' STO. These effects of sub-components on STO were seen in the all PCK maps so it can be constituted Figure 5.1. As a conclusion, it can be said that gifted students acted as an amplifier to shape the participant teacher's PCK. On the other hand, KoIS and KoA played an important role at the second part of planning part while the teacher was planning all topics. The teacher built her lesson based on students' prior knowledge and abilities so she had to assess students' prior knowledge. In order to assess, she used particular instructional strategies, examples, models, etc. Then, the teacher considered the students' possible misconceptions or learning difficulties and she planned how to overcome those difficulties by using specific instructional strategies. After instruction, she assessed the effectiveness of her teaching. Thus, the second part of her planning stage, KoIS and KoA shaped the teacher design making process.

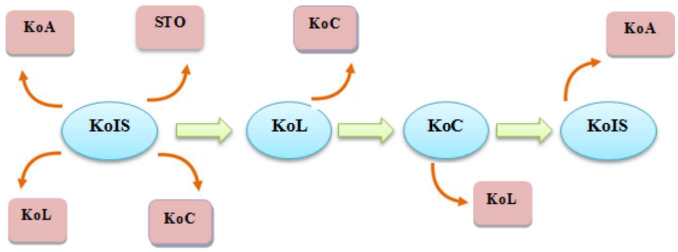


Figure 5.2. The Summary of the Teacher's PCK Components Interactions in Teaching Practices

In order to summarize the teacher's PCK maps for teaching practice process, Figure 5.2 can be constructed. The teacher generally used her PCK components in four teaching segments. The first segment has KoIS as initiative component interacting four components, in other words, the teacher reflected and presented the most pedagogical behaviors in this segment. She generally started to ask questions to students in order to assess their previous knowledge, alternative conceptions, or misconceptions, which mean that KoIS interplayed with KoA. After controlling or recalling students' prior knowledge, she focused on targeted concept and she introduced related topics by using selected instructional strategies. Namely, it meant that KoIS interacted with STO. As the course progresses, there were generally some learning difficulties in which students did not understand the concepts, explanations, or activities arising from the teacher's teaching. In this regard, it was represented the interaction between KoIS and KoL in the first teaching segment. The final interaction between KoIS and KoC in this segment appeared when the teacher tried to handle learning difficulties by offering more detailed explanation or more concrete examples. In this situation, she generally presented the formula of related concepts or phenomena which was called enrichment activity. This pattern can be seen (the first teaching segment) in her all teaching practices. Some topics including less complex content such as hoops, gears, hoists, and simple machines consisted of only one teaching segment. However, the number of interactions changed according to the nature of the topic.

Second teaching segment consists of one interaction of KoL and KoC. In this segment, we can emphasize the effects of knowledge of characteristics of gifted students on the teacher's teaching practices. It was mentioned in the part of "4.2.3.1 Knowledge of Characteristics of Gifted Students" that the students asked a lot of questions and negotiated the teacher explanations. Thus, they could realize upper class concepts which were not targeted to teach by the teacher and they extended the targeted concept into upper class concepts. For this reason, the teacher had to explain upper class concepts which were called enrichment activities. Similar to planning maps, the characteristics of gifted students' sub-component acted as an amplifier to shape the teacher teaching.

It was not easy for the teacher to explain or to teach enrichment activities due to the fact that each activity had some requirements, for instance, students should have prior knowledge, mathematical skills and abilities which were stated clearly in part of "4.2.3.2 Knowledge of Requirements for Learning". These enrichment activities led to appear a lot of learning difficulties, which was called the interaction of KoC and KoL in the third teaching segment.

The last teaching segment is related to the interaction of KoIS and KoA. This segment generally appeared in the complex topics such as work and energy, kinetic energy, levers, pulleys, spinning wheels, and friction force. The segment was used by the teacher when she summarized the topics and assessed the students' conceptual understanding on related topics. If the students had still learning difficulties or lack of knowledge about targeted concepts, the teacher tried to deal with them by using specific instructional strategies. As a result, this teaching segment consisted of the last part of the teacher teachings.

After conclusion of the interaction findings of this study, some factors were discussed with science teacher PCK literature. It has been suggested to investigate the interaction of PCK components because there have been still unclear points in the PCK literature (Abell, 2008; Henze et al., 2008; Lee & Luft, 2008; Magnusson et al., 1999; Park & Oliver, 2012). In this respect, the scholars have been trying to find out the relationships among both knowledge bases (Cochran et al., 1991; Fernandez-Balboa & Stiehl, 1995; Friedrichsen et al., 2009; Kaya, 2009) and PCK components (Akın, 2017; Aydın et al., 2015; Aydın & Boz, 2013; Demirdöğen, 2016; Ekiz Kıran, 2016; Henze et al., 2008; Kaya, 2009; Padilla & van Driel, 2011; Park & Chen, 2012). In addition to above studies, it was expected that the present study provided the interaction PCK components literature with valuable evidence and information about how a science teacher plans and practice related science concepts.

The first factor requiring the discussion with literature was that the interactions of PCK components act in a topic-specific nature. Stated differently, each teacher PCK map both in planning and in practicing process had different interactions such as binary, triple, or more than. Even though the study included one middle school science teacher, and she reflected same planning pattern, both planning and practicing maps differed from each other. It is reasonable to think that each topic or sub-topic includes concepts with different level of complexity which can be difficult to learn for students and to teach for the teacher. Moreover, if a teacher has strong knowledge about students' misconceptions on a specific topic, the teacher reflects more robust PCK in teaching process (Park & Oliver, 2008). In this respect, the participant teacher was not aware of students' possible alternative conceptions derived from classroom observations, if she was; she would present more various PCK maps. As a conclusion, the topic-specific issue is a common result for the studies among to investigate the interaction of PCK components (Akın, 2017; Aydın & Boz, 2013; Park & Chen, 2012).

The second factor was the effect of STO on teacher PCK. The general acceptance about STO is that it is over-arching knowledge, shapes or moderates the other PCK components, and teachers' decisions making process (Aydın & Boz, 2013; Boesdorfer & Lorsbach, 2014; Friedrichsen & Dana; 2005; Friedrichsen et al., 2009; Friedrichsen et al., 2011; Grossman, 1990; Magnusson et al., 1999; Park & Chen, 2012). To illustrate, having didactic orientation hinder to use authentic assessment techniques (Aydın, 2012; Ekiz Kıran, 2016) or teachers' beliefs and values might mediate the selection of assessment strategies including science process skills or nature of science (Abell, 2007). Another example also appeared in Park and Chen's (2012) study. Their participant teacher had teacher-centered orientation and he presented generally lecturing and discussion. In doing so, he accepted that his students came to class without misconceptions, and his students only could not remember previous learning. Therefore, the participant teacher ignored to check the misconceptions during teaching of related topics, in other words, the teacher' STO hindered the interaction between KoIS and KoL.

Similar to general acceptance of STO, in this study, STO interacted with (1) KoC (the teacher's goal is to teach curriculum objectives or enriched activities), (2) KoL (the teacher's goal is to teach prior knowledge of related topic in order to provide meaningful learning, or in order to enhance students' abilities; creativity, reasoning, and thinking), (3) KoIS (the teacher's goal is to apply student-centered instructional strategies in order to enhance students' conceptual understanding), and (4) KoA (the teacher's goal is to assess the students' learning at the end of the course) in binary way. Each binary interaction reflected the influence of the teacher STO on other components. Moreover, the effect of STO can be seen all PCK maps in planning process.

On the other hand, this study provides STO literature with new evidence that knowledge of characteristics of gifted students and enrichment curriculum affected the teacher' STO. Gifted students shaped the teacher goals and purposes by adding additional goals such as determining gifted students' special abilities, and enhancing those abilities by utilizing specific educational activities. Moreover, the teacher' view of science teaching and learning was shaped by the gifted students, which tended the teacher' STO change from teacher-centered to student-centered orientation, because, traditional strategies are not enough to meet the needs of gifted students (Winstanley, 2007). Stated differently, the school context including gifted students shaped the teacher' STO. It can be interpreted with Park and Chen's (2012) results in this manner. In their study, although participant teachers planned science lesson based on similar topics and similar planning process, their PCK maps differed from each other, namely, the students' feedbacks during the teaching might shape the teachers' PCK maps. Moreover, the evidence stemmed from Henze et al. (2008)

might support to effect of gifted students on teachers' STO. In their study, participant science teachers presented teaching in more or less student-centered tendency, and during the study, the teachers' goal and objectives did not significantly change over time, namely, the non-gifted students did not shape of the teachers' STO or KoC.

The third factor requiring the discussion with literature was the frequencies of interaction components. Some studies focusing on the interaction components did not find out any evidence about KoA and its effect of teachers' PCK. For example, Kaya (2009) clarified that KoA did not connect other components significantly. Friedrichsen et al.'s (2009) participant teachers did not take place any assessment strategies in their works. Another study was conducted by Padilla and van-Driel (2011), and they found as KoA at a certain relationship with others but at least level, similar to studies results arising from Aydın and Boz (2013), and Aydın et al. (2015). However, Park and Chen (2012) were able to detect KoA effects on teachers' PCK. In their study, by the way, KoC was at least interaction components and it generally interacted with KoIS. KoA was more interacted with KoL and KoIS than STO and KoC because the participants used informal assessment skills such as questioning or monitoring in order to determine students' performance. In this respect, KoL and KoIS were more employed in interaction with KoA. In the present study, parallel to Park and Chen's (2012) results, KoA was used by the teacher so many times both in planning process and teaching process. Stated differently, the participant teacher did not ignore to monitor her students' learning performance.

As regarding the frequencies other components, STO appeared at all the stages of teaching practices, because this component reflected the teacher's goal and proposes in the planning map. While KoIS and KoA did not appear as initiative components in the planning stage, KoIS interacted with others as an initiative component more than others in practicing maps because the teacher was in a facilitator role and her speech, demonstrations, explanations, questions, or guidance were suitable instructional strategies from the beginning to the end of each class. Moreover, KoL, KoC, or KoA sometimes acted as an initiative component in the practicing maps. On the other hand, KoL is the most interacted component in planning. As regarding other studies results on interaction PCK components, KoL, KoIS, and KoC were used as central components (Akın, 2017). KoL and KoIS were also more interacted components but KoL and KoC were active components in order to understand students' prior knowledge or alternative conceptions (Aydın & Boz, 2013). Another study showed that KoC was the most enhanced component through CoRe mentoring program (Aydın et al., 2015). Similar to previous studies, KoL and KoIS played an important role during planning and practicing process, and they were more interacted than other components (Park and Chen, 2012). To sum up, the results of above studies show how PCK components interact in a complex way in terms of understanding science teacher PCK.

The fourth factor requiring the discussion with literature was the complexity of the interactions. This study included a mapping approach involving teaching segments and decision making segments (there are no any relationships among two segment, namely, the arrows between two segments represent the sequence of the segments), one-way interactions (for example, KoIS-KoC means that the teacher uses a specific instructional strategy or activity in order to provide gifted students with enrichment activities.), and the complex level of interaction (some interactions involve three components, some of them include four or more than). This demonstration of the interactions varies from topic to topic. Henze et al. (2008) showed the PCK development process and which components enhance the development of other components by drawing one-way or mutually interaction. Similarly, Aydın (2012) explained the interactions among PCK components in mutual and one-sided interactions. Moreover, Aydın and Boz (2013), they explained the interactions in simple way including that one component informs other component such as KoL informed KoIS, and in a complex way including that one component was affected or informed by the other two or more components.

In this present study, the complexity of the interactions was explained based on the number of components. If an interaction includes two components, it can be said that it is simple interaction such as KoL-KoA or KoIS-KoA. However, if an interaction includes three or more components, it can present complex pedagogical activities or decisions such as KoL-KoIS-KoA or KoL-KoIS-KoA-KoIS-KoA-KoIS due to the fact that the teacher tried to handle a specific misconception or learning difficulty.

The demonstration of interactions with mapping approach can be considered as in a linear process but the linear process shows the sequence of the components. As it is known that the interaction of PCK components are affected by various factors or beliefs which might act simultaneously while teaching a specific topic (Fernandez-Balboa & Stiehl, 1995). When teaching a specific topic, teaching segments might be affected by characteristics of students, classroom context, and other knowledge bases, personal emotional factors in terms of both teacher and students. Therefore, it is impossible to investigate and demonstrate all factors in a map. In this respect, the study only focused on the teacher's PCK components, and the drawing of component in a linear was the best way to demonstrate the complexity of the interaction among PCK components. To sum up, in order to provide effective teaching, teacher knowledge and it's all aspects are utilized in greatly complex in nature (Park & Oliver, 2008), PCK components act as a whole (Magnusson et al., 1999), and knowledge bases is not separated (Cochran et al., 1991; Grossman, 1990; Marks, 1990).

5. 3 Implications and Recommendations

In light of the findings emerged and the issues discussed, the study can provide researchers focusing on both gifted teacher education and non-gifted teacher education, pre-and in-service teacher education, curriculum developers, and textbook writers with valuable implications.

First, for science teacher educators, this study provided an example of how work and energy, simple machines, and friction force were effectively planned and practiced by a gifted students' science teacher. Feedbacks arising from students during teaching related concepts are also important for science teacher literature because this study clarified an example of how the students' learning difficulties, alternative conceptions and the lack of students' prior knowledge were handled by particular techniques. Moreover, the PCK maps show the detailed and complex nature of the teacher's PCK when the participant teacher faced related learning difficulties. Each of decision making and teaching segments in the PCK maps can guide the science teacher educators how related science topics are taught for middle school students.

Second, for the science educators, having strong SMK (Parker & Heywood, 2000) or robust PCK (Gess-Newsome et al., 2017) is not guarantee to provide effective science learning. In this regard, teachers need to engage in well-designed professional development programs in order to enhance their knowledge and experiences in specific topics such as work and energy, simple machines, and friction force. Science topics have specific characteristics including more abstracts concepts, learning difficulties, or misconceptions. In this respect, it should not be allowed that teachers obtain those characteristics by their own experience through trial and error method, namely, no need to reinvent the wheel. For this reason, this study provides the science educators with specific teaching and learning experiences in terms of three physics topics and sub-topics.

Third, for the science educators, in addition to in service teachers, pre-service teachers also need to engage in professional development programs in order to enhance their PCK. For well-designed professional development programs, the results of this study might shape the content of the programs in terms of how work and energy, simple machines, and friction force topics are taught for middle school students. In doing so, the study results should be modified and integrated for professional development program in order to how pre-service teachers enhance their PCK component such as STO; from didactic to reform based, KoA; from informal to formal applications, KoIS; from topic-specific to subject specific instructional strategies. Moreover, this study also showed that some abilities such as nature of science and science process skills were ignored during decision making and teaching process of teaching specific science topics. Thus, the university courses such as science methods or teaching experience might be enriched though the integration of how to present the nature of science and science process skills, how to determine the students' learning difficulties, misconceptions, or pre-requirements, and how to handle all of them. It is expected that well-designed professional development programs allow the great impact on the pre-service teachers' PCK development.

Fourth, for the science educators again, as we know from gifted students' literature, they need a particular differentiated educational program differed from regular curriculum materials (Çalıkoğlu & Kahveci, 2015; Gilman, 2008; Winstanley, 2007). Therefore, the designing of such programs including the characteristics of gifted students need to have a specific experience in terms of determining of gifted learners needs, modifying curriculum materials and objectives, or designing new enrichment curriculum. In this respect, this study might introduce science teacher educators the effectiveness of enrichment activities including upper class objectives, materials, or activities. Stated differently, this study is an example of content based enrichment type including secondary science classes' contents and concepts.

Fifth, for curriculum developers and textbook writers, this study investigated the nature of topic-specific science teacher PCK in terms of work and energy, simple machines, and friction force. It is clear from the results of this study and science teacher literature, we know that these topics and sub-topics have abstract and complex nature (Ahtee & Johnston, 2006; Ginn & Waters, 1995; Johnston & Ahtee, 2006; Loughran et al., 2006), and both teachers and students have some alternative conception about those topics (Kruger, 1990; Trumper, 1998; Marulcu & Barnett, 2013; Hope & Townsend, 1983). In this regards, the study was able to determine both students learning difficulties and the teacher pedagogical difficulties, and how the teacher handled those difficulties by using specific strategies. I believe that the results of this study can guide the curriculum developers and textbook writers. They can consider the results of this study including students' alternative conceptions, learning difficulties, or pre-requirements through highlighting the students' needs and providing alternative strategies to overcome them while they are designing curriculum materials or textbook.

Finally, this study presents some recommendations about topic-specific nature of teacher PCK and interaction of PCK components for education research fields both science teacher education and gifted students education. In this respect, this study investigated a science teacher's PCK and its components interactions while teaching work and energy, simple machines, and friction force topics. More research also needs to conduct in similar topics and context because the study has a case study involving a science teacher, and the results of this study can be supported with future research. Moreover, other topics in a similar subject should be investigated to determine the nature of PCK and its components interactions in order to complete the interaction of PCK puzzle, and to find out the complex and dynamic nature of interactions.

In addition, this study showed how a science teacher designed particular enrichment activities for gifted students through modifying regular curriculum. In addition to this study, there is a great need for gifted students' education to be supported by more evidence based research in terms of designing enrichment activities and determining the effectiveness of students' performance. It seems reasonable to suggest that future studies can focus on designing enrichment activities including more science process skills, nature of science, creative and productive skills. In the literature, the skills are more ignored part on gifted students' education.

Lastly, using PCK map approach in this study provides science teacher education with different point of view about how PCK components are constructed by the teacher both planning and practicing process while teaching of the related topics. For the future studies, the PCK map approach should be integrated in PCK studies through enhancing weakness of this mapping approach. In doing so, PCK map approach will be developed and provide more strength and quality the results about the interaction of PCK components over the particular topics. As a conclusion, science teacher education needs to gain more useful insights in order to practice those implications.

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APPENDICES

A. CARD-SORTING ACTIVITIES (IN TURKISH)

Üstün Yetenekli Öğrencilerin Fen Bilimleri Öğretmenleri için Kart Gruplama Aktivitesi

İş ve Enerji konusu için

1.Kuvvet, iş ve enerji arasındaki ilişkiyi araştırmanın etkili bir yolu, öğrencilerin düşünme sürecini ve becerilerini kullanabilecekleri; gözlem yapabilecekleri, veri toplayabilecekleri, verilerden bir sonuca ulaşabilecekleri, sonuçları arkadaşlarıyla tartışabilecekleri bir sınıf ortamı hazırlamaktır. (Process)

2. Fiziksel anlamda iş kavramını ve birimini anlatmanın etkili bir yolu düz anlatım veya tartışma yoluyla power point sunusundan bilgiyi aktarmaktır. (Didactic)

3. Kinetik ve çekim potansiyel enerjisini anlatmanın etkili bir yolu konu ile ilgili farklı ve zor örnekler vererek sorular çözmektir. (Academic Rigor)

4. Günlük hayatta algıladığımız iş kavramı ile bilim insanlarının tanımladıkları fiziksel anlamdaki iş kavramı arasındaki farkı anlatmanın etkili bir yolu, öğrencilerin konuyla ilgili ön bilgilerini ortaya çıkaracak sorular sorarak veya kavram haritası gibi aktiviteler kullanarak öğrencilerdeki yanlış kavramları belirlemek ve sonrasında sahip oldukları yanlış kavramları gidermeye çalışmaktır.(Conceptual change)

5. Bir cisme hareket doğrultusuna dik olarak etki eden kuvvetin, fiziksel anlamda iş yapmadığını öğretmenin etkili bir yolu, öğrencilere konuyla ilgili modeller, görseller sunarak veya öğrencilerinde dâhil olduğu aktiviteler yaptırarak hareket doğrultusuna dik ve paralel kuvvet arasındaki farkı anlamalarını sağlamaktır. (Activity-driven)

6. Kinetik enerjinin sürat ve kütle ile olan ilişkisini öğretmenin iyi bir yolu, kütlelerinin ve süratlarının değiştirilebileceği araç-gereçlerin kullanıldığı, "sabit süratte kütle ile kinetik enerji" ve "sabit kütlede sürat ve kinetik enerji arasındaki ilişkiyi keşfedebilecekleri bir laboratuvar aktivitesi düzenlemektir. (Discovery)

7. Enerji dönüşümünün günlük yaşamdaki uygulama alanlarını öğretebilmenin etkili bir yolu, öğrencilere 3-4 hafta boyunca çeşitli enerji türleri ile ilgili bilgi

toplayabilecekleri, araştırma yapabilecekleri ve bu bilgileri arkadaşlarıyla paylaşabilecekleri bir proje hazırlatmaktır. (Project-based science)
8. Fiziksel anlamda yapılan bir işin uygulanan kuvvet ve cismin aldığı yolla doğru orantılı olduğunu öğretmenin etkili bir yolu; öğrencilere "Hangi durumlarda yapılan işin büyüklüğü arttırılabilir?" sorusu yöneltilerek öğrencilerin araştırma sorusunu belirleyebildiği, gözlemler yapıp, deney düzenekleriyle hipotezlerini test edip veri toplayabildikleri bir ortam sağlamaktır. (Inquiry)
9. Bir cismin çekim potansiyel enerjisini etkileyen faktörleri öğretmenin etkili bir yolu; bir cismin ağırlığı ve yüksekliğini farklı durumlarda öğretmen eşliğinde inceleyerek, öğrencilerden süreci gözlemlemeleri ve sonuçları tartışmaları istenir. (Guided Inquiry)

Basit Makineler konusu için

1.Basit makineler konusunu öğretmenin etkili bir yolu, öğrencilerin düşünme sürecini ve becerilerini kullanabilecekleri; gözlem yapabilecekleri, veri toplayabilecekleri, verilerden bir sonuca ulaşabilecekleri, sonuçları arkadaşlarıyla tartışabilecekleri bir ortam hazırlamaktır. (Process)
2. Öğrencilere Basit makineler konusunu anlatmanın etkili bir yolu düz anlatım veya tartışma yoluyla power point sunusundan bilgiyi aktarmaktır. (Didactic)
3. Basit makineler ve özellikleri konusunu öğretmenin etkili bir yolu, konu ile ilgili farklı ve zor örnekler vererek sorular çözmektir. (Academic Rigor)
4. "Bir işi yaparken basit makine kullanmanın enerji tasarrufu sağlamayacağını, sadece iş yapma kolaylığı sağlayacağını anlatmanın etkili bir yolu, öğrencilerin kavramlarla ilgili ön bilgilerini ortaya çıkaracak sorular sorarak veya görsel metaryeller (video, model, simulasyon) kullanarak yanlış kavramları belirlemek ve sonrasında sahip oldukları yanlış kavramları gidermeye çalışmaktır. (Conceptual change)
5. Eğik düzlem konusunu öğretmenin etkili bir yolu öğrencileri konuyla ilgili aktivitelere dâhil etmektir. Eğik düzlem yardımıyla oyuncak bir aracı belirli bir yüksekliğe, eğimleri farklı olan dört yoldan gidilerek ulaşması sırasında kuvvetten

kazancın yoldan kaybın, yoldan kazancın kuvvetten kaybın yaşandığı durumları test etmektir. (Activity-driven)

6. Kaldıraç kavramını öğretmenin iyi bir yolu, kaldıraç modeli oluşturularak, destek noktasının, kuvvet kolu ve yük kolunun uzunluklarının hangi durumlarda kuvvetten kazanç ve yoldan kayıp ya da tersi bir durumu keşfedebilecekleri bir laboratuvar aktivitesi düzenlemektir. (Discovery)

7. "Basit makineler işleri nasıl daha kolay hâle getirir?" sorusuna cevap bulmanın etkili bir yolu, öğrencilere 3-4 hafta boyunca farklı basit makine çeşitlerini araştırarak basit makinelerin geçmişte ve günümüzde insanlığa sunduğu yararlarla ilgili bilgi toplayabilecekleri, araştırma yapabilecekleri ve bu bilgileri arkadaşlarıyla paylaşabilecekleri bir proje hazırlatmaktır. (Project-based science)

8. "Basit makineler uygulanan kuvveti nasıl artırır?", sorusuna cevap bulmanın etkili bir yolu, öğrencilerden çeşitli basit makineleri kullanarak "uygulanan giriş kuvvetinden daha büyük bir çıkış kuvveti elde edilebilecekleriyle" ilgili araştırma yapmaları, modeller kurarak hipotezlerini test etmeleri, veri toplamaları ve elde ettikleri sonuçları sınıfta tartışmalarına izin vermektir. (Inquiry)

9. Sabit ve hareketli makaralar arasındaki farklı öğretmenin etkili bir yolu; kuvvet yönünün değişeceği ve böylece iş yapma kolaylığı sağlayacak farklı durumları öğretmen eşliğinde inceleyerek, öğrencilerden süreci gözlemlemeleri ve sonuçları tartışmaları istenir. (Guided Inquiry)

Enerji ve sürtünme kuvveti

1.Sürtünme kuvveti konusunu öğretmenin etkili bir yolu, öğrencilerin düşünme sürecini ve becerilerini kullanabilecekleri; gözlem yapabilecekleri, veri toplayabilecekleri, verilerden bir sonuca ulaşabilecekleri, sonuçları arkadaşlarıyla tartışabilecekleri bir ortam hazırlamaktır. (Process)

2. Enerji ve sürtünme kuvveti konusunu anlatmanın etkili bir yolu düz anlatım veya tartışma yoluyla power point sunusundan bilgiyi aktarmaktır. (Didactic)

3. Enerji ve sürtünme kuvveti konusunu öğretmenin etkili bir yolu, konu ile ilgili farklı ve zor örnekler vererek sorular çözmektir. (Academic Rigor)

4. “Sürtünme kuvveti ile yüzey ilişkisi ve sürtünme kuvveti ile hareket yönü arasındaki ilişkiyi” anlatmanın etkili bir yolu, öğrencilerin kavramlarla ilgili ön bilgilerini ortaya çıkaracak sorular sorarak veya görsel materyaller (video, model, simulasyon) kullanarak yanlış kavramları belirlemek ve sonrasında sahip oldukları yanlış kavramları gidermeye çalışmaktır. (Conceptual change)

5. Sürtünme sonucunda enerjideki meydana gelecek dönüşümleri göstermenin etkili bir yolu öğrencilere konuyla ilgili aktiviteler yaptırmaktır. (Activity-driven)

6. Sürtünme kuvveti ile yüzey ilişkisini öğretmenin iyi bir yolu, öğrencilerin farklı yüzeydeki cisimlerin hareketlerinden yola çıkarak pürüzlü yüzeylerde sürtünme kuvvetinin fazla olduğunu keşfedebilecekleri bir laboratuvar aktivitesi düzenlemektir. (Discovery)

7. Öğrencilerin sürtünmenin olumlu ve olumsuz yönlerini öğretmenin etkili bir yolu, öğrencilere 3-4 hafta boyunca günlük hayatta kullandığımız araç gereçleri araştırarak, sürtünme kuvvetine hangi durumlarda çok, hangi durumlarda az ihtiyaç duyulduğuyla ilgili bilgi toplayabilecekleri, araştırma yapabilecekleri ve bu bilgileri arkadaşlarıyla paylaşabilecekleri bir proje hazırlatmaktır. (Project-based science)

8. “Sürtünme kuvveti nelere bağlıdır?”, sorusuna cevap bulmanın etkili bir yolu, öğrencilerden farklı yüzeylerde farklı kütledeki cisimlerin hareketlerini inceleyebilme, hipotezlerini test edebilme, veri toplamaları ve elde ettikleri sonuçları sınıfta tartışmalarına izin vermektir. (Inquiry)

İlköğretim Fen Bilimleri program amaçları

1.Bir fen bilimleri öğretmeni olarak üstün yetenekli öğrencileriniz için yapabilecek en iyi şey onların liselere giriş sınavlarından yüksek puan almalarını sağlamaktır. Bu amaca ulaşmak için konuyu işledikten sonra mümkün olduğu kadar liselere giriş sınavı için soru çözersiniz. (Türk eğitim sisteminin gerçeği)

2. Bir fen bilimleri öğretmeni olarak amacınız, üstün yetenekli öğrencilerinizin bireysel yeteneklerinin farkında olmalarını ve kapasitelerini geliştirerek en üst düzeyde kullanmalarını sağlamaktır. (Bilsem amaçları)

3. Üstün yetenekli öğrencilerin yaşam projelerini gerçekleştirmek için uygun olan konularda, öğrencilerin bilimsel çalışma disiplini edinmelerine imkân sağlayan şartları, ortam ve fırsatları oluşturularak, sorunlar çözmeye ya da ihtiyacı karşılamaya yönelik çeşitli projeler gerçekleştirmelerini sağlamaktır. (Bilsem amaçları)
4. Kuvvet ve hareket konularını anlatmanın etkili bir yolu, öğrencilere ilgili kavramların tarihsel gelişimlerinden bahsederek derse giriş yapmaktır. (curriculum goal: history of deveopment of concept)
5. Üstün yetenekli öğrencilerin fen bilimleri ile ilgili alanlarda yeteneklerini keşfederek ve bu alanlarda eğitimlerini sürdürmelerini sağlamanın etkili bir yolu, fen ve teknoloji alanlarında çalışan insanların hayatımızı nasıl değiştirdiklerinin olumlu örneklerini konu bazında öğrencilere sunmaktır. (Bilsem amaçları: affective domain)
6. Kuvvet, iş ve enerji alanında yapılan teknolojideki gelişmelerin çevreye ve topluma olan etkilerini öğretmenin etkili bir yolu konu ile ilgili uzman kişilerle (bilim insanı, mühendis, vb) görüşme/mülakat yapmalarını istemektir. (curriculum goal: STSE)

Kart gruplama aktivitesi: Görüşme soruları

Kart gruplama aktivitesine başlamadan önce öğretmenlere sorulacak sorular

1. Okulunuzda fen konularının öğretilmesi/aktivitelerinin yapılmasının sebepleri ve amaçları nelerdir?
2. Bahsettiğiniz bu amaçları/hedefleri nasıl belirlediniz? Bu amaçları/hedefleri belirlemenize neler yardımcı oldu? (üstün yetenekli öğrenciler, geçmiş deneyimleriniz, yönetim, vs.)
3. Okulunuzdaki amaçların/hedeflerin ilköğretim okullarındaki amaçlar/hedeflerden ayrıldığı noktalar var mı? Varsa nelerdir?

Kart gruplama aktivitesinde öğretmenlerden kartları 3 gruba ayırmaları istenir. 1. gruptaki kartlar öğretmenin yaptığı öğretimi/öğretim yöntemini yansıtan, 2. gruptaki kartlar öğretmenin öğretimini yansıtmayan ve 3. gruptaki kartlar ise öğretmenin öğretimini yansıtıp yansıtmadığından emin olmadığı kartları içerir.

Kart gruplama aktivitesi tamamlandıktan sonra aşağıdaki sorular sorulur.

1. .... nolu kart yaptığınız öğretim ile paralel olduğunu düşünüyorsunuz. .... nolu kart fen öğretiminiz için olan hedeflere/amaçlara (daha önce bahsedilen) ulaşmanıza nasıl yardımcı olur?
2. Üstün yetenekli öğrencilere sunduğunuz öğretim ile öğretiminizi yansıttığınız senaryolar arasında benzerlik var mıdır?
3. Birinci gruptaki kartların ortak özellikleri nelerdir? .... nolu senaryo ile .....nolu senaryonun farklı yönleri nelerdir / benzer yönleri nelerdir?
4. Kart gruplama aktivitesindeki senaryolar dışında .... konusunda kullanmak istediğiniz bir yöntem var mı? Varsa nelerdir? Ayrıca söylediğiniz bu yöntemler amaçlarınıza ulaşmanıza nasıl yardımcı olacaktır?
5. ..... ünitesindeki konuları normal öğrencilerle (yetenekli olmayan) işlemiş olsaydınız gruplamada değişiklik yapar mıydınız?
6. ikinci gruptaki kartlar öğretiminizi neden temsil etmemektedir? Bu kartların ortak özellikleri nelerdir?
7. İkinci gruptaki kartları normal öğrenci grubunun fen öğretimde kullanır mısınız?
8. İkinci gruptaki kartlarda ne tür değişiklikler yaparak üstün yetenekli öğrencilerin fen öğretiminde kullanırsınız?
9. Üçüncü gruptaki kartların öğretiminizi yansıtmasından neden emin olmadınız? Bu kartların öğretiminizi yansıtması için herhangi bir değişiklik yapılabilir mi?
10. Eklemek istediğiniz başka bir şey var mı?

B. CONTENT REPRESENTATION (CoRe) (IN TURKISH)

İçerik gösterim tablosu	Konuyla ilgili önemli fen fikirleri/kavramları		
	Fikir/ kavram 'A'	Fikir/ kavram 'B'	Fikir/ kavram 'C'
Öğrencilerinize bu fikir/kavram hakkında ne öğretmeyi düşünüyorsunuz?			
Öğrencilerinizin bu fikir/kavramı bilmeleri neden önemlidir?			
Bu fikir/kavram hakkında henüz öğrencilerinizin öğrenmesinin erken olduğunu düşündüğünüz başka neler biliyorsunuz?			
Bu fikir/kavramı öğretirken karşılaşacağınız zorluk ve sınırlamalar nelerdir?			
Bu fikir/kavramı öğretirken, öğretiminizi etkileyecek öğrencilerdeki düşünce ve inanışlar hakkındaki bilgileriniz nelerdir?			
Bu fikir/kavramı öğretmenizi etkileyecek diğer faktörler nelerdir?			
Bu fikri/kavramı öğretirken öğretim prosedürünüz nedir? Ve neden bu tür öğretim yöntem ve stratejilerini seçtiniz?			
Bu fikir/kavram hakkında öğrencilerin anladıkları ve karıştırdıkları durumları nasıl belirlersiniz?			

C. INTERVIEW QUESTIONS (IN TURKISH)

Bu görüşmenin amacı öğretmenler tarafından .... konusu için hazırlanan içerik gösterim tablosunda, araştırmacı tarafından anlaşılmayan noktaların ya da araştırmacıya ilginç/farklı gelen durumların açıklanması için yapılacaktır.

Konuyla ilgili 1. ana fikir/kavram

İçerik gösterim tablosunda 1. Ana fikir/kavram olarak ….. belirlemişsiniz? ….. konusu içerisinden neden bu ana fikir/kavramı seçtiniz? Bu ders için amacınız nedir? Üstün yetenekli öğrencilerin hangi özelliklerini göz önüne alarak bu ana fikir/kavramı belirlediniz?

1. Üstün yetenekli öğrencilerinize bu fikir/kavram hakkında neyi öğretmeyi düşünüyorsunuz?

- Bu fikir/kavramı seçerken ilköğretim programından faydalandınız mı? programda ….. konusunda kavramların sıralanışı nasıldır?
- Sizce üstün yetenekli öğrencilerin bu konuyla ilgili öğrenmesi gereken önemli kavramlar/noktalar nelerdir?
- Üstün yetenekli öğrenciler için ilköğretim programı yeterli midir? Yoksa zenginleştirdiğiniz ve hızlandırdığınız aktiviteleriniz var mı? Varsa bunlara nasıl karar veriyorsunuz?
- Sizce üstün yetenekli öğrenciler bu anlatılacak fikir/kavramı kolaylıkla anlayabilecekler mi?

2. Bu fikir/kavramın öğretilmesi üstün yetenekli öğrenciler için neden önemlidir?

- Bu fikir/kavram öğrencilere nasıl bir katkı sağlayacak (öğrencilerin zihinsel gelişimi, yeteneklerinin farkına varması, var olan yeteneklerinin gelişimi, günlük hayatla ilişkilendirilmesi)?
- Öğrenciler elde ettikleri bilgi ve becerileri nerede ve nasıl kullanacaklar?

3. Bu fikir/kavram hakkında henüz öğrencilerinizin öğrenmesinin erken olduğunu düşündüğünüz başka neler biliyorsunuz?

- Konuyla ilgili sınırlamanız nedir? Neden bu konuları şimdilik öğrencilere öğretmeyi uygun bulmuyorsunuz?
- Üstün yetenekli öğrencilerin olması bu sınırlamayı nasıl etkiler?

4. Bu fikir/kavramı öğretirken karşılaşacağınız zorluk ve sınırlamalar nelerdir?

- Bu fikir/kavram öğretiminde karşılaşacağınız zorluklar nelerdir?
- Bu fikir/kavramı öğretirken, öğrenciler için kafa karıştıran, anlaşılmayan, kavram yanılgısı veya alternatif kavramlar var mı?
- Anlatılan ileri seviyedeki konular öğrencilerde kavram yanılgısı oluşturur mu? Bunu nasıl belirler/ölçersiniz? Bu durumu ortadan kaldırmak için planladığınız bir şeyler var mı?

5. Bu fikir/kavramı öğretirken, öğretiminizi etkileyecek öğrencilerdeki düşünce ve inanışlar hakkındaki bilgileriniz nelerdir?

- Konuyla ilgili öğrenciler hangi ön bilgilere sahip olması gerekli? Ön bilgide farklılıklar oluşuyorsa bu öğretiminizi nasıl etkiliyor?
- Öğrencilerin entelektüel seviyesi (bilim çocuk dergisi, diğer dergi ve kitaplar, öğrencilerin ilgi alanları) bu fikir/kavramı öğretmeyi nasıl etkiliyor?
- Öğrencilerin öğrenme stilleri bu fikir/kavramı öğretmeyi nasıl etkiliyor?

6. Öğretiminizi etkileyecek diğer faktörler nelerdir?

- Bu fikir/kavramın öğretimini etkileyen diğer faktörler nelerdir? Bu faktörler öğretiminizi nasıl etkilemektedir (olumlu-olumsuz)?
- Bu faktörler fikir/kavram veya konu seçiminizi etkiliyor mu? Bu konuyu seçerken ve öğretirken kendinizi ne kadar özgür hissediyorsunuz?

7. Bu fikri/konuyu öğretirken öğretim prosedürünüz nedir? Ve neden bu tür öğretim yöntem ve stratejilerini (analoji, gösteri deneyi, benzetim/simülasyon, grafik, günlük hayattan örnekler) seçtiniz?

- Bu yöntem/stratejiyi neden seçtiniz? Bu yöntemi kullanmanız konudan konuya değişir mi?
- Öğretim stratejilerini seçerken üstün yetenekli öğrencilerin etkisi oluyor mu? Cevabınız evet ise bu etkiyi biraz anlatır mısınız?
- Kullanacağınız yöntem ve stratejilerin etkili olacağını düşünüyor musunuz? Bu düşünceye nasıl vardınız?

8. Öğrencilerin konuyu anlayıp anlamadığını nasıl ölçersiniz?

- Özel bir ölçme değerlendirme teknikleriniz var mı? Bu teknikler konuya veya öğrenciye göre değişiyor mu?
- Üstün yetenekli öğrenciler var olması ölçme değerlendirme yönteminizi etkiliyor mu? Etkiliyorsa açıklar mısınız?
- Öğrenci etkinliklerini değerlendirirken nasıl bir yol izliyorsunuz? Süreç temelli mi? Yoksa ürün temelli mi?
- Öğrenci performanslarını değerlendirirken nelere dikkat ediyorsunuz?
- Öğrencilerde var olan kavram yanılgılarını tespit ediyor musunuz? Cevabınız evet ise biraz açıklar mısınız?

Öğretmenlerin ilgili konuyu sunduktan sonra sorulacak mülakat soruları

İçerik gösterimi tablosu ile sunumunuz arasındaki farklar var mı? Planladığınız gibi bir sunum oldu mu? Farklı olan noktaları açıklayabilir misiniz?

İçerik gösterimi tablosunun;

Birinci sorusuyla ilgili olarak, sizce anlatmak için seçtiğiniz ..... fikir/kavram yerinde oldu mu? Öğrencilerin buna tepkisi nasıldı? Hangi noktalar çıkartılmalı ya da yeni bilgi/kavram eklenmeli?

İkinci sorusuyla ilgili olarak, konuyu öğrettikten sonra konunun önemi hakkında düşüncelerinizde değişiklik oldu mu? Eklemek veya çıkarmak istediğiniz noktalar nelerdir?

Üçüncü sorusuyla ilgili olarak, konunun sınırlarında bir değişiklik oldu mu? Eklemek istediğiniz ya da çıkarmak istediğiniz kavram/bilgi/örnek oldu mu?

Dördüncü sorusuyla ilgili olarak, planlarınız dışında öğretim sırasında karşılaştığınız zorluklar ve sınırlamalar oldu mu?

Beşinci sorusuyla ilgili olarak, sunum sırasında karşılaştığınız ilginç bir durum oldu mu?

Altıncı sorusuyla ilgili olarak, planlarınız dışında öğretiminizi etkileyen diğer faktörler nelerdir?

Yedinci sorusuyla ilgili olarak, planladığınız öğretim sürecinde değişiklik oldu mu? Varsa nelerdir? Ve hangi faktörler sizi bu değişikliği yapmaya zorladı?

İçerik gösterimi tablosunda …. Yöntemi/stratejisini kullanmayı planlamıştınız fakat … yöntemi/stratejisini kullandınız. Bu değişikliği yapmanızın nedenleri ve buna sebep olan faktörler nelerdir?

Sekizinci sorusuyla ilgili olarak, öğretim sürecinizi değerlendirdiğinizde başarıya ulaştınız mı? Sizce öğretiminizde eksik olan noktalar var mı?

İçerik gösterimiyle ilgili sorular tartışıldıktan sonra gözlem sırasında araştırmacıya ilginç gelen noktalar öğretmenlerle tartışılır?

….. şu konuların/kavramların öğretimi sırasında …… ilginç bir durum oldu. Ve siz ….. şeklinde davrandınız? Bu davranışınızın arkasındaki neden nedir?

Seçilen konuların öğretimi bittikten sonra içerik gösterimi ve sunumları arasındaki farkların öğretmenler tarafından değerlendirilmesi

1. ….., ……., ve ……… konuları arasındaki öğretiminizde farklılıklar var mı? Bu farklılıklar nereden kaynaklanır?
2. Hangi konuların öğretimi diğerlerinden kolaydır veya zordur? Kolay veya zor olmasının nedenleri nedir?
3. ….., ……., ve ……… konuları ile ilgili olarak, öğretim programları, amaçları, öğretim yöntem ve stratejileri, öğrenci bilgisi, ve değerlendirme hakkındaki bilgilerinizi karşılaştırabilir misiniz?
4. ….., ……., ve ……… konularını öğrettikten sonra değerlendirme açısından bir faklılık oldu mu? Her bir konuyu nasıl değerlendirdiniz?

D. OBSERVATION PROTOCOL (IN TURKISH)

Tarih:

Konu:

Ders başlamadan önce fiziksel çevreyle (sınıf ortamı, öğrenci sayısı, öğretim materyalleri ve diğer öğretimi etkileyebilecek faktörler) ilgili gözlem yapılır.

Gözlemci ders süresince öğretmenlerin sahip oldukları pedogojik alan bilgisinin alt bileşenleri hakkında notlar alacaktır ve ilginç noktaları öğretmenlerle konuşacaktır.

1. Fen öğretiminin amaç ve hedeflerinin bilgisi

- Öğretmenin feni öğretme amacı gözlenir ve ilgili fikir/kavramı öğretme şekli incelenir. İlgili konunun amaçları seçilirken, öğretimi yapılırken (uygulanan stratejiler), programdaki var olan materyel kullanımı ve öğrencilerin değerlendirmesine kadar geçerli süreçte öğretmen davranışları gözlenir.

2. Öğretim programı bilgisi

- Öğretmenin ilgili konudaki kavramların öğretim sırasını belirlemesi ve ders sırasında bu sıralama yaptığı değişiklikler gözlenir.
- Öğretmen ilgili konuyu aynı sınıf seviyesinde başka fen konularıyla ilişki kurup kurmadığı ve ilgili konuları diğer disiplinlerle (matematik, türkçe, sosyal) ilişkilendirip ilişkilendirmediği gözlenir.
- Öğretmenin üstün yetenekli öğrenciler için zenginleştirdiği programı, ders süresince sınıfta olanlara dayandırarak planında bir değişiklik yapıp yapmadığı gözlenir.

3. Öğrenci bilgisi

- Öğretmen öğrencilerin konuyla ilgili ön bilgilerinin ve becerilerinin farkında olup olmaması ve öğrencilerde var olan bireysel farklılıkları ele alıp almaması gözlenir.
- Öğretmenin öğrenciyle olan ilişkisi, öğrencilerin sorularına öğretmenin verdiği tepki gözlenir.
- Öğrencilerin konuyla ilgili karşılaştıkları sorunlar ve bu sorunların çözümünde öğretmenin etkililiği gözlenir.

- Öğretmen ilgili konuyu öğretirken öğrencilerin sıklıkla yaptığı hataları ele alıp almaması, konuyla ilgili oluşabilecek alternativ kavramlar veya kavram yanılgılarının farkında olup olmaması gözlenir.

- Öğretmenin üstün yetenekli öğrencilerin yeteneklerinden dolayı ders süresince karşılaştığı olumlu ve olumsuz davranışlara (öğrencilerin sordukları soru düzeyi veya çeşidi gibi) tepkisi gözlenir.

4. Ölçme değerlendirme bilgisi

- Öğretmen ders süresince öğrencilerin ön bilgilerini ölçüp ölçmemesi gözlenir.

- Öğretmenin konuyla ilgili öğrencilerin zorlandığı noktaları veya öğrencilerde var olan kavram yanılgılarını tespit edip etmemesi gözlenir.

- İlgili konu ve kavramın öğretildiğini değerlendirmek için öğretmenin ders sırasında, ders sonunda ve ünite sonlarında ölçüm yapıp yapmaması gözlenir.

5. Öğretim yöntem bilgisi

- Öğretmenin ilgili kavaramı açıklamak için kullandığı stratejiler (subject-specific veya topic specific) gözlenir.

- Öğretmenin ders sırasında öğrencilerin zorlandığı konularda, ilgili kavramın daha kolay ve iyi öğretilmesi için farklı aktivite, etkinlik, model, anoloji, ödev gibi stratejilerle dersin akışında bir değişiklik yapıp yapmadığı gözlenir?

- Öğretmenin üstün yetenekli öğrenciler için kullandığı özel bir öğretim stratejisi kullanıp kullanmadığı gözlenir.

E. THE PERMISSIONS FROM MINISTRY OF NATIONAL EDUCATION

T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

ÖĞRENCİ ... DAİRESİ BAŞ... ĞI
Ev. Arş. Md. Saat :

Sayı : 14588481/605.99/2021895 21/05/2014
Konu: Araştırma İzni
(Burak ÇAYLAK)

ORTA DOĞU TEKNİK ÜNİVERSİTESİNE
(Öğrenci İşleri Daire Başkanlığı)

İlgi : a) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 2012/13 nolu genelgesi
b) 13/05/2014 tarih ve 2509 sayılı yazınız.

Üniversiteniz doktora öğrencisi Burak ÇAYLAK'ın "Üstün Yetenekli Öğrencilerin Öğretmenlerinin Pedagojik Alan Bilgilerinin Konuya Özgü Doğasının Biyoloji Konularında İncelenmesi" konulu tez önerisi kapsamında uygulama yapma isteği uygun görülmüş ve araştırmanın yapılacağı İlçe Milli Eğitim Müdürlüğüne bilgi verilmiştir.

Anketlerin uygulama yapılacak sayıda çoğaltılması ve çalışmanın bitiminde iki örneğinin (CD ortamında) Müdürlüğümüz Strateji Geliştirme-1 Şube Müdürlüğüne gönderilmesini arz ederim.

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İlköğretim Bölümü

Gönderen : Prof. Dr. Canan Özgen
IAK Başkanı

İlgi : Etik Onayı

Danışmanlığını yapmış olduğunuz İlköğretim Bölümü öğrencisi Burak Çaylak'ın "Üstün Yetenekli Öğrencilerin Öğretmenlerinin Pedagojik Alan Bilgilerinin Konuya Özgü Doğasını Biyoloji Konularında İncelenmesi" isimli araştırması "İnsan Araştırmaları Komitesi" tarafından uygun görülerek gerekli onay verilmiştir.

Bilgilerinize saygılarımla sunarım.

Etik Komite Onayı

Uygundur

10/04/2014

Prof.Dr. Canan Özgen
Uygulamalı Etik Araştırma Merkezi
(UEAM) Başkanı
ODTÜ 06531 ANKARA

F. TURKISH SUMMARY/ TÜRKÇE ÖZET

BİR FEN BİLİMLERİ ÖĞRETMENİNİN PEDAGOJİK ALAN BİLGİSİNİN KONUYA ÖZGÜ DOĞASININ İNCELENMESİ; ÜSTÜN YETENEKLİ ÖĞRENCİLERİN ÖĞRETMENİNİN DURUMU

GİRİŞ

Fizik konularının öğrenilmesi ve öğretilmesi hem öğretmenler açısından hem de öğrenciler açısından zorlu bir süreçtir (Ahtee & Johnston, 2006; Hammer, 1996). Bu nedenle fizik konularının öğretilmesi için başta alan bilgisi, genel pedagojik bilgiler, pedagojik alan bilgisi (PAB) gibi birçok bilgi ve uygulamanın eş zamanlı uygulanması gereklidir. Bir dersin planlama bölümünde öğretilecek kavramla ilgili önce öğretmenin hedef ve davranışları belirlenir ve sonra ilgili kazanımlar programdan seçilir. Öğrencilerin var olan bilgilerini de ele alarak en uygun öğretim stratejileri belirlenir ve değerlendirme süreci inşa edilir (Magnusson ve ark., 1999). Bu kısım sadece bir fen kavramının öğretilmesinin planlama aşamasıdır ve uygula aşamasında öğrenciler birçok öğrenme zorlukları yaşarlar. Sonuç olarak öğretmenin bu zorlukları gidermesi için bir kavramlara ve konulara özgü, alan bilgisi ve genel pedagojik bilgilerin dışında sahip olması ve etkili bir şekilde uygulaması gereken bir bilgiye "PAB" a ihtiyacı vardır.

PAB alan bilgisini öğrencilere en uygun şekilde anlatabilmek için kullanılan en kullanışlı sunumlar, en güçlü analojiler, gösterimler, örnekler ve açıklamalar olduğu bir sunum şeklidir (Shulman, 1986). Çünkü öğretmenler belirli bir konunun anlatılmasında en uygun sunumlar, gösterimler, uygulamalar kullanırlar ve bu özel sunumları, becerileri veya diğer pedagojik davranışları tecrübe ederler (Shulman, 1987). Bu süreçte alan bilgisini uygulamaya geçirmede PAB önemli bir rol oynar. Bu yüzden PAB ortaya atıldıktan sonra birçok araştırmacı tarafından kullanılmış ve incelenmiştir. Ama hala birçok açıklanamayan kısımları mevcuttur (Abell, 2008; Loughran ve ark., 2004).

Magnusson ve ark. (1999) PAB için bir model geliştirdiler ve fen bilimleri öğretmenlerinin PAB'larının bu modele göre incelenebileceğini vurguladılar. Bu modele göre bir öğretmenin PAB'ı konuya özgü değişmektedir ve bu değişiklik PAB'ın 5 alt bileşenlerinden kaynaklanmaktadır; bir fen bilimleri öğretmeninin (1) fen öğretimi oryantasyonu, (2) öğretim programı bilgisi, (3) öğrenci bilgisi, (4) öğretim stratejileri bilgisi ve (5) değerlendirme bilgisi.

Bu çalışmada üstün yetenekli öğrencilerin öğretmenin kuvvet hareket konularında PAB kullanımı incelenmiştir ve Magnusson ve ark.'nın (1999) PAB modeli tüm bileşenleri ile bu araştırmada kullanılmıştır. Bu çalışmanın amacı üstün yetenekli bir fen bilimleri öğretmeninin iş ve enerji, basit makineler ve sürtünme kuvveti konularında PAB ve PAB'ın tüm bileşenlerini incelemektir. İkinci amaç ise bu konularda öğretmenin PAB bileşenlerinin etkileşimini hem planlama ve hem de uygulama aşamasında incelemektir. Bu amaçlar doğrultusunda aşağıdaki araştırma soruları belirlenmiştir.

1. Üstün yetenekli öğrencilerin fen bilimleri öğretmeninin iş ve enerji, basit makineler ve sürtünme kuvvetini öğretirken kullandığı PAB'ı nedir?
    a. Üstün yetenekli öğrencilerin fen bilimleri öğretmeninin iş ve enerji, basit makineler ve sürtünme kuvvetine ilişkin kullandığı fen bilimleri oryantasyonu nedir?
    b. Üstün yetenekli öğrencilerin fen bilimleri öğretmeninin iş ve enerji, basit makineler ve sürtünme kuvvetine ilişkin kullandığı öğretim programı bilgisi nedir?
    c. Üstün yetenekli öğrencilerin fen bilimleri öğretmeninin iş ve enerji, basit makineler ve sürtünme kuvvetine ilişkin kullandığı öğrenci bilgileri nedir?
    d. Üstün yetenekli öğrencilerin fen bilimleri öğretmeninin iş ve enerji, basit makineler ve sürtünme kuvvetine ilişkin kullandığı öğretim stratejileri bilgisi nedir?

e. Üstün yetenekli öğrencilerin fen bilimleri öğretmeninin iş ve enerji, basit makineler ve sürtünme kuvvetine ilişkin kullandığı değerlendirme bilgisi nedir?

2. Fen bilimleri öğretmeninin iş ve enerji, basit makineler ve sürtünme kuvveti konularını öğretirken kullandığı PAB bileşenleri nasıl etkileşim yapar?
   a. Fen bilimleri öğretmeninin iş ve enerji, basit makineler ve sürtünme kuvveti konularını planlarken kullandığı PAB bileşenleri nasıl etkileşim yapar?
   b. Fen bilimleri öğretmeninin iş ve enerji, basit makineler ve sürtünme kuvveti konularını öğretirken kullandığı PAB bileşenleri nasıl etkileşim yapar?

YÖNTEM

Çalışma Deseni

Bu çalışmada nitel araştırma yöntemlerinden örnek-durum araştırma deseni kullanılmıştır. Durum araştırma deseni gerçek yaşam olaylarının anlamlı ve bütünsel açıdan anlamayı sağlar (Yin, 2009). Durum çalışması ayrıca bireylerin karmaşık davranışları arasındaki ilişkiyi açıklamada kullanılır. PAB'ın doğası gereği öğretmen bilgisi ve davranışları karmaşıktır. Bu davranışları ortaya çıkarmak için ilk elden verilerin toplanması ve araştırmacının fiziksel öğrenme-öğretmen ortamına dahil olması gereklidir. Bu yüzden her bir öğretmen PAB çalışmalarında bir durum çalışması oluşturabilir (Shulman, 1987). Bu çalışmada ortaokulda görev yapan bir fen bilimleri öğretmeni (üstün yetenekli öğrencilerin öğretmeni) tekli durum deseni olarak seçilmiştir. Katılımcı öğretmenin iş ve enerji, basit makineler ve sürtünme kuvveti konularının planlaması ve öğretimi durum çalışmasına dahil edilmiştir.

Bu çalışmaya katılan kadın öğretmen toplamda üç yıllık bir öğretmenlik deneyimine sahip olup, bir yıl üstün yetenekli olmayan ortaokul öğrencileri ile ve iki yıl üstün yetenekli öğrencilerle öğretmenlik yapmıştır. Fen fakültesi fizik bölümünden mezun olan öğretmen, katı hal fiziğinde yüksek lisans derecesi almıştır ve öğretmenlik sertifikası için pedagojik formasyon eğitimini tamamlayıp özel bir okulda öğretmenlik yapmaktadır.

Bu çalışmaya katılan öğretmen fizik bölümü mezunu olduğu için üç fizik konusu 7. Sınıf kuvvet ve hareket ünitesinden "iş enerji, basit makineler ve sürtünme kuvveti" çalışmanın amacı doğrultusunda seçilmiştir. Fen öğretmen eğitimi alan yazına göre, yeterince güçlü alan bilgisi öğretmenlerin PAB gelişimlerini desteklemektedir (Abell, 2007; Magnusson ve ark., 1999). Bu yüzden çalışmaya katılan öğretmenin alan bilgisini etkili bir şekilde öğretim ortamına yansıttığı varsayılmaktadır.

Araştırmanın yapıldığı okula bakıldığında, çalışmaya katılan öğretmen üstün yetenekli öğrencilerin öğretim gördüğü özel bir kolejde çalışmaktadır. Okul ilköğretim ve ortaöğretim üstün yetenekli öğrencilerden oluşmaktadır. Üstün yetenekli öğrenciler zekâ ölçeği olan WISC-III IQ puanına göre (120 ve üzeri puan üstün yeteneklilik olarak kabul ediliyor) okula seçilip kayıt hakkı kazanmaktadırlar.

Veri toplama süreci

Fen öğretmen eğitimi alan yazın PAB çalışmalarında çoklu veri toplama tekniklerini ve uzun süreli gözlem yapılmasını önermektedir (Abell, 2008; Baxter & Lederman, 1999). Bu yüzden bu çalışmada çoklu veri toplama teknikleri kullanılmıştır; kart-gruplama aktivitesi, içerik gösterim tablosu, mülakatlar ve sınıf gözlemleri. Bu çalışmaya katılan öğretmenin fen öğretimine olan inançlarını ve oryantasyonunu belirlemek için, çalışmanın başlangıcında her bir konu öğretimi yapılmadan önce öğretmenle kart-gruplama aktivitesi yapılmıştır. Daha sonra öğretmenin planlama sürecindeki PAB bileşenlerini belirlemek için ders planı olarak içerik gösterim tablosu doldurması istenmiştir. Bu çalışmada ayrıca yarı-yapılandırılmış görüşmeler kullanılmış ve bu görüşmeler iki kısımdan oluşmaktadır.

Birincisi ön görüşmeler, öğretmenin planlama sürecinde bilgi ve becerilerini daha ayrıntılı öğrenmek için her bir içerik gösterim tablosundan sonra yapılmıştır. İçerik gösterim tablosunu doldurmak öğretmenler için meşakkatli bir süreç olduğu için (Loughran ve ark., 2006) ve bazı sorular çalışmaya katılan öğretmen tarafından istenilen seviyede cevaplandırılmadığı için ön mülakat yapılmış ve bu eksik bölümler ön görüşmeler doğrultusunda tamamlanmıştır.

Ön görüşmeler yapıldıktan sonra, öğretmenin planlama ve uygulamadaki bilgi ve becerilerini karşılaştırmak için öğretmenin konuları öğretme süreci gözlemlenmiştir. Sınıf gözlemleri PAB çalışmalarında önemli yer tutmaktadır çünkü PAB sınıf uygulamasında ortaya çıkmaktadır (Gess-Newsome, 2015). Haftalık 3 ders saati olmak üzere 2 aya yakın öğretmenin öğretim performansı gözlemlenmiştir. Son olarak her bir konunun öğretilmesinden sonra öğretmenin yapmış olduğu öğretim sırasında anlaşılmayan durumları, beklenmedik öğrenci ve öğretmen davranışlarını açığa kavuşturmak için son görüşmeler yapılmıştır.

Araştırma sorularına cevap bulmak için veri toplama araçları birincil ve ikincil kaynak olarak ayrılmıştır. Örneğin birinci araştırma sorusu ve alt soruları ele alındığında, öğretmenin fen öğretimine karşı oryantasyonunu belirlemek için kart-gruplama aktiviteleri ve sınıf gözlemleri birincil kaynak veri toplama aracı olarak ele alınmıştır. Diğer veri toplama araçları ikincil kaynak olarak birincil kaynak verileri destekler nitelikte kullanılmıştır. Benzer şekilde diğer PAB bileşenlerini (program, strateji, değerlendirme ve öğrenci bilgisi) açıklamak için içerik gösterim tablosu, ön-görüşmeler ve sınıf gözlemleri birincil veri toplama araçlarıdır. Diğer yandan, son-görüşmeler ikincil veri toplama kaynağı olarak kullanılmıştır. İkinci araştırma sorusu ele alındığında, planlama sürecindeki PAB bileşenlerinin etkileşimlerini belirlemek için ön-görüşmeler birincil kaynak olarak kullanılmış ve içerik gösterim tabloları ikincil kaynak olarak ele alınmıştır. Benzer şekilde uygulama sürecindeki PAB bileşeni etkileşimlerinde sınıf gözlemleri birincil kaynak ve son-görüşmeler ikincil kaynak olarak ele alınmıştır.

Veri analizi süreci

Bu çalışma nitel araştırma yöntemlerinden birini benimsediği için ayrıntılı analiz yaklaşımlarının kullanılmasıyla analiz birimlerinin karşılaştırılmasına dayanan bütüncül bir süreci izlemiştir (Merriam, 2009; Patton, 2002). Öncelikle veri setlerini oluşturmak için toplanan veriler düzenlenmiş ve analiz için hazırlanmıştır. Sonrasında veri kodlama süreci başlamıştır. Bu çalışmada araştırma sorularına cevap bulabilmek için üç farklı yaklaşım kullanılmıştır; PAB ortaya çıkarmak için derinlemesine analiz, içerik analizi ve sabit karşılaştırma (constant comparative) analizi.

Derinlemesine PAB analizi. Toplanan dijital veriler sözel analiz setleri haline getirildikten sonra Magnusson ve ark.'nın (1999) PAB modeline göre tümden gelim yöntemiyle kodlanmıştır çünkü nitel analizler öncelikle alan yazından gelen kodlarla analize başlar (Patton, 2002). Bu yüzden açık kodlama yöntemiyle tüm PAB bileşenleri ayrı ayrı kodlanmıştır. Kodlama sürecinde yeni kodlar keşfedilmiştir örneğin, üstün yetenekli öğrencilerin karakteristik özellikleri ve zenginleştirilmiş program. Bu tür bilgi ve davranışlar ise tümevarım yöntemiyle kodlanıp ilgili kategorilere eklenmiştir.

İçerik analizi. Doğrudan gözlenemeyen insan davranışlarının analizinde kullanılan bir tekniktir (Fraenkel & Wallen, 2009). Bu analiz tekrar eden kelime veya kategorilerin sözel veri setinde keşfedilmesinde kullanılır ve kategori sayılarını azaltarak çıkarım yapılmasını kolaylaştırır (Patton, 2002). Bu çalışmada araştırmanın ikinci araştırma sorusuna cevap bulmak için bu analiz kullanılmıştır, yani, öğretmenin planlama ve uygulamadaki kullandığı PAB bileşenlerinin etkileşimini belirmeye yardımcı olmuştur.

PAB bileşenlerinin etkileşimi bu çalışmada şu şekilde tanımlanmıştır; iki ya da daha fazla bileşenin öğretmen tarafından herhangi bir pedagojik bir eylemi tamamlamak için kullanılmasıdır. Örneğin, öğretmenin bir PAB bileşenini herhangi bir öğrencilerin alternatif kavramlarını tespit etmek veya gidermek için kullanmasıdır ya da bir bileşenin öğrencilere kavramsal öğretimin sağlanması için kullanılmasıdır. Örnek vermek gerekirse, öğretmen üstün yetenekli öğrencilerin özelliklerini bildiği için öğrenciler için zenginleştirilmiş aktiviteler uygulamak istiyor ve tartışma yöntemiyle ilgili kavramları kazandırmayı hedefliyor. Bu örnekte STO (fen öğretimi oryantasyonu)-KoC (program bilgisi)-KoIS (öğretim strateji bilgisi) etkileşim içindedir.

İçerik analizine başlarken alan yazından gelen kodlar ve kategoriler kullanılır (Fraenkel & Wallen, 2009). Bu yüzden Park ve Chen (2012) ve Aydın ve ark.'nın (2015) PAB bileşenlerinin etkileşimleri referans alınarak kodlama işlemine başlanmıştır. Daha sonra yeni etkileşimlerle karşılaşılmış ve yeni kategoriler oluşmuştur. Planlama sürecinde 21 etkileşim kategorisi ve uygulama sürecinde ise 10 etkileşim kategorisi oluşmuştur.

Sabit karşılaştırmalı analizi. Bu analiz PAB bileşenlerinin etkileşim haritalarını oluşturmada kullanılmıştır. Tekrar eden döngüsel bir analiz şeklidir ve kodlarla kodlar, kodlar ve kategoriler, kategoriler ile kategoriler, son olarak kategoriler ve kavramlar karşılaştırılarak yeni bir kavram ya da teori ortaya atılır (Bryant, 2013). Bu çalışmada elde edilen kodlar kodlarlar, kodlar kategorilerle, kategoriler ise kategorilerle karşılaştırılarak tümevarım yaklaşımıyla PAB etkileşim haritaları oluşturulmuştur. Bu süreç veriler doyuma ulaşana kadar yani yeni kategori ve harita oluşmayana kadar devam etmiştir.

Her bir harita öğretmenin ya planlama sürecindeki ya da uygulama sürecindeki kullandığı PAB bileşenlerini temsil eder. Her bir harita öğretim bölümlerinden oluşur ve her bir öğretim bölümü içerisinde bir ya da daha fazla PAB bileşeninin etkileşimini içerir. Bir öğretim bölümü oluşturulurken benzer etkileşimi başlatan bileşen aynı öğretim bölümüne eklenir. Bu yöntem haritaların hem okunmasını hem de daha fazla yer kaplamayıp ekonomik alan kullanımını sağlar. Öğretim bölümleri içerisindeki numaralar ise etkileşim sırasını göstermektedir. Geniş bileşenler her bir öğretim bölümlerindeki bir etkileşimi başlatan bileşeni gösterir. Her bir etkileşimi başlatan geniş bileşenler arasında ise (büyük oklar) herhangi bir pedagojik davranış veya ilişkiyi göstermemektedir. Sadece etkileşimin akış yönünü ve sırasını göstermektedir. Sonuç olarak bu şekilde etkileşim haritaları oluşturulmuştur.

Alan yazın incelendiğinde farklı bir etkileşim haritala yöntemi kullanılmaktadır. Beşgen model (pentagon model) Park ve Chen (2012) tarafından geliştirilen modele göre her bir PAB bileşeni eşit bir şekilde etkileşime girebileceği varsayılmaktadır. Beşgen model oluşturulurken önce etkileşim kategorileri oluşturulur ve öğretim bölümleri veya parçaları oluşturulur. Her bir bölüm veya öğretim parçası ele alınan konunun zorluk ve karışıklık düzeyine göre farklı etkileşimler içerir. Bu modelde iki bileşen arasındaki etkileşimler incelenir ve etkileşim sayıları hesaplanarak model oluşturulur. Eğer bir haritada etkileşim sayıları ve çeşitleri farklı ise diğer haritalardan, ilgili konunun anlatılması ve öğretilmesi zordur denilebilir.

Bu çalışmada Park ve Chen (2012) etkileşim kategorileri kullanılmış ancak beşgen model araştırmanın temel gösterim şekli olarak benimsenmemiştir ama PAB bileşimlerinin etkileşim sayısının daha iyi anlaşılması için beşgen model her bir konu için hazırlanmıştır. Araştırmacı tarafından geliştirilen model ise verilerin gösterimi ve yorumlamasında temel alınmıştır. Beşgen modelin neden yorumlama kısmında kullanılmadığının birkaç sebebi var. Beşgen model bu çalışma verilerini açıklamada yeterli değildir çünkü beşgen model sadece etkileşimlerin sayılarını göstermektedir ya da etkileşimlerin zayıf ve güçlü yönlerini göstermektedir. Diğer bir zayıf yönü beşgen modelin ise beşgen model sadece ikili etkileşimleri göstermektedir. Ancak araştırmacı tarafından geliştirilen modelde ise üçlü, dörtlü ve daha fazla etkileşimleri göstermektedir. Diğer bir sınırlılık ise beşgen model bütün konuların toplamı olarak son bir özet sunmaktadır. Ancak araştırmacının modelinde ise her bir konunun başlangıcından sonunda kadar ki öğretmenin hem planlama hem de uygulama sürecindeki bilgi ve becerilerini temsil etmektedir. Son olarak, araştırmacı tarafından geliştirilen modelde aynı PAB bileşenler arasındaki etkileşimlerde gösterilmektedir. Örneğin KoL-KoL etkileşimi üstün yetenekli öğrencilerde var olan kavram yanılgısının giderilmesi zordur" anlamına gelir. Ya da üstün yetenekli öğrencilerin özelliklerinden dolayı zenginleştirilmiş etkinliklere ihtiyaç duyarlar. Buna benzer etkileşimler beşgen modelde gösterilmemektedir.

SONUÇLAR VE TARTIŞMA

Araştırma soruları doğrultusunda çalışmanın bulguları şu sıraya göre açıklanmıştır; öğretmenin fen öğretimine karşı oryantasyonu, öğretim program bilgisi, öğrenci bilgisi, öğretim stratejisi bilgisi ve değerlendirme bilgisi. Daha sonra öğretmenin kullandığı PAB bileşenlerinin etkileşimlerinin bulguları açıklanmıştır.

Fen öğretimi oryantasyonu

Bu bileşen üç alt-başlık altında incelenecektir; öğretmenin fen öğretimi amaç ve hedeflerine karşı inançları, öğretmenin fen öğretime karşı inançları ve son olarak öğretmenin bilimin doğasına karşı inançları.

İlk alt bileşene bakıldığında, öğretmen belirli amaç ve hedeflere sahip, örneğin kavramsal öğretim yapmak, okul amaç ve hedefleri, üstün yetenekli öğrenciler için ayrı hedefler gibi çoklu amaç ve hedefler sergilenmektedir. Katılımcı öğretmen için kavramsal öğretim ilk amaçlar arasında yer alır ve kavramları Milli Eğitim Bakanlığınca (2006) sunulan ilköğretim programından takip etmektedir. Bu tür kavram öğretimi genellikle öğretmenler tarafından benimsenen bir amaçtır (Ahtee & Johnston, 2006). Ayrıca, katılımcı öğretmen öğrencilerini liselere hazırlık sınavına hazırlamak gibi birincil bir hedefi yoktur çünkü öğrenciler arasında farklı alanlarda yetenekli üstün yetenekli öğrenci bulunmaktadır. Öğretmenin benimsediği diğer bir amaç ise öğrencilerin fen bilimlerine karşı olan ilgisini artırmak. Bunu yaparak hem öğrencilerin özel yeteneklerini keşfetmeye çalışıyor hem de bu özel yetenekleri geliştirmeyi hedeflemektedir. Alan yazın incelendiğinde üstün yetenekli öğrenciler normal öğretim programının yanında farklılaştırılmış eğitim fırsatlarına ihtiyaç duymaktadır (Bangel ve ark., 2010; Croft, 2003; Çalıkoğlu & Kahveci, 2015). Buna paralel olarak katılımcı öğretmen üstün yetenekli öğrencileri için zenginleştirilmiş aktiviteler sunmayı hedeflemektedir. Sonuç olarak öğretmen bu alt bileşen hakkında çoklu amaç ve hedefler sergilemektedir.

İkinci alt bileşen olan öğretmenin fen öğretimine karşı inançlarına bakıldığında kart-gruplama aktiviteleri, ders planları ve sınıf gözlemleri analiz edilerek sonuca ulaşılmıştır. Kart gruplama aktiviteleri sonucuna göre, öğretmen öğrenci merkezli fen öğretim oryantasyonuna sahiptir örneğin, araştırma-sorgulamaya dayalı öğretim, keşfetme, kavramsal değişim, ya da bilimsel süreç becerileri kazandırma gibi. Fakat sınıf gözlemleri incelendiğinde öğretmenin geleneksel öğretim yöntemlerini kullandığı görülmüştür. Yani, öğretmenin inançları ve uygulaması arasında bir uyuşmazlık mevcuttur. Bu durum fen bilimleri öğretmenleri arasında genellikle yaygındır (Abell, 2007; Aydın ve ark., 2014; Campbell ve ark., 2017). Çünkü öğrenci merkezli uygulamaların yapılamamasının bir çok nedeni vardır örneğin sınav temelli öğretim (Aydın ve ark., 2014), yoğun öğretim programı (Samuelowicz & Bain, 1992), aktiviteleri planlama ve uygulama için yeterli zamanın olmaması (Friedrichsen & Dana, 2005). Bu açıdan bakıldığında katılımcı öğretmen yeterli zamana sahip olmadığı için gerekli uygulamaları planlayıp öğrencilerine sunamamaktadır. Ancak, katılımcı öğretmenin fen öğretimine karşı oryantasyonu için tek bir oryantasyona (öğretmen merkezci-geleneksel) sahiptir diyemeyiz çünkü öğretmen bir den fazla fen öğretimi oryantasyonuna sahiptir. Sınıf gözlemleri sırasında öğretmen 2 ayrı tümevarım laboratuvar uygulaması yaptırdı ve öğrencileri ilgili kavramları keşfedebildiler. Bir de öğrencilerin üstün yetenekli olmalarından dolayı geleneksel düz anlatım yöntemi öğrenciler tarafından şekillenip öğrenci merkezli bir yapıya bürünmektedir. Çünkü öğrenciler öğretmenin her anlattığı kavramı ve açıkladığı olayları sorguladıkları için tartışma ortamı yaratılıyor ve öğrenciler anlatılan her ifadeyi kolay kolay kabul etmiyorlar. Bu yüzden öğretmen daha somut ve açıklayıcı örnekler sunmak zorunda kalıyor. Bu bazen gösteri, analoji, model kullanma gibi stratejilerle öğretmenin düz anlatımını zenginleştiriyor. Yani üstün yetenekli öğrenciler öğretmenin geleneksel oryantasyonunu az ya da çok reform temelli oryantasyona taşıyorlar.

Üçüncü alt bileşen olan öğretmenin bilimin doğasına karşı olan inançlarına baktığımızda herhangi bir öğretim hem planlamada hem de uygulamada karşımıza çıkmamıştır. Bu durum maalesef öğretmenler arasında yaygın bir sonuçtur (Aydın ve ark., 2014; Boesdorfer & Lorsbach, 2014; Demirdöğen, 2016; Ekiz Kıran, 2016; Schneider & Plasman, 2011).

Özet olarak, katılımcı öğretmen karışık ve disiplin özellikli (konuya özgü olmayan) bir oryantasyona sahiptir. Bu bulgu alan yazındaki araştırmalarla da örtüşmektedir (örn., Abell, 2007; Aydın ve ark., 2014; Friedrichsen & Dana, 2005). Bir diğer önemli bulgu ise öğretmenin oryantasyonu okulun özelliğinden yani üstün yetenekli öğrencilerin olmasından etkilenmektedir. Öğretmen genel amaç ve hedeflerin yanında üstün yetenekli öğrenciler için ek olarak hedefler belirlemektedir, örneğin üstün yetenekli öğrencilerin yeteneklerinin belirlenmesi ve bu yeteneklerin uygun aktiviteler yardımıyla geliştirilmesi gibi. Ayrıca üstün yetenekli öğrenciler öğretmenin öğretim oryantasyonunu da şekillendirmektedir. Normalde öğretmen düz anlatım uygulayarak ilgili kavram ve konuları öğretmeyi hedeflerken, öğrenciler ders sırasında daha aktif hale gelerek öğrenci merkezli öğretim ortamını sağlamaktadırlar. Çünkü üstün yetenekli öğrenciler için klasik öğretim stratejileri yeterli değildir (Winstanley, 2007). Bu bulgu Park ve Oliver (2008) çalışmasındaki bulgularla paraleldir. Diğer yandan, alan yazınında belirttiği gibi (Boesdorfer & Lorsbach, 2014; Grossman, 1990; Magnusson ve ark., 1999) öğretmenin fen öğretimi oryantasyonu diğer PAB bileşenlerini etkilemektedir.

Öğretim programı bilgisi

Öğretmenin birincil amacı öğrencilerine kavramsal öğretimi sağlamak olduğu için katılımcı öğretmen ilköğretim ve ortaöğretim programlarına bağlı kalarak onları etkili bir şekilde kullanmaktadır. Aslında öğretim programının sıkı sıkı takip edilmesiyle yapılan planlama ve uygulamalar mesleğe yeni başlayan öğretmenlerden beklenen bir davranıştır (Schneider & Plasman, 2011). Ancak katılımcı öğretmen gerek ilköğretim programındaki kavramların yerlerini değiştirerek gerekse orta öğretim programından zenginleştirilmiş aktiviteler planlaması öğretim programını etkili bir şekilde kullanabildiğinin birer kanıtıdır. Genellikle öğretmenlerin program bilgilerini artırmak için özel eğitim programları, sertifika programları düzenlenmektedir (Friedrichsen ve ark., 2009). Ancak bu çalışmaya katılan öğretmen herhangi bir eğitim programına katılmamıştır ama MEB (2006) öğretim programı öğretmenler için zengin bir rehber niteliğindedir çünkü içerisinde ilgili kavram ve konuların kazanımları, aktiviteleri, sınırlılıkları, öğrencilerde bulunabilecek alternatif kavram yanılgıları, öğretim metot ve değerlendirme stratejileri bulunmaktadır. Bu bağlamda katılımcı öğretmen etkili bir şekilde fen kavramları arasında hem dikey hem de yatay program ilişkilerini kurabilmektedir. Bu bulgu Aydın ve ark. (2014) çalışmasının bulguları tarafından desteklenmektedir.

Bu çalışmadaki öğretmenin program bilgisi konu temelli bir yapıya sahiptir. Aydın ve ark.'nın (2014) çalışması bu bulguyu desteklerken alan yazındaki diğer çalışmalar öğretim program bilgisinin disiplin temelli ya da özellikli bir yapıda olduğunu açıklar (Gess-Newsome, 2015; Shulman, 1986).

Bir diğer önemli program bilgisi ise zenginleştirilmiş programdır çünkü üstün yetenekli öğrenciler zenginleştirilmiş öğretim materyallerine ihtiyaç duyarlar (Çalıkoğlu & Kahveci, 2015; Gilman, 2008). Bu çalışmada öğretmenin birincil amacı öğretim programındaki 7. Sınıf kavramların öğretimini sağlamaktır. Ancak öğrencilerin üstün yetenekli olmasından dolayı, öğrenciler ilgili konu kavramları kısa sürede öğrenmektedir ve geri kalan zaman diliminde öğretmen zenginleştirilmiş aktiviteler sunmaktadır. Bu aktivitelerin planlanması ve uygulanması bir bilgi türü olarak bu çalışmada ele alınmıştır. Zenginleştirilmiş aktiviteler ileri ve detay düzeyde konu ve uygulamaları içeren aktivitelerdir (Freeman, 1998; Kim, 2016; Thomson, 2006). Bu bağlamda, katılımcı öğretmen ilgili kavramların zenginleştirilmiş aktivitelerini hazırlamak için ortaöğretim programını kullanarak ileri düzey kavram ve uygulamaları öğrencilere zenginleştirilmiş aktivite olarak sunmaktadır.

Alan yazın incelendiğinde üstün yetenekli öğrenciler için ileri ve detay bilgiye ihtiyaç olduğu vurgulanır (Çalıkoğlu & Kahveci, 2015; Newman & Hubner, 2012; Shaughnessy & Sak, 2015). Ancak öğrencilere sadece bilgi temelli içeriğin sunulması da eleştirilir ve üstün yetenekli öğrencilere bilgi ile birlikte beceri de kazanacakları uygulamalar gereklidir (Renzulli, 2012), örneğin bilimsel süreç becerileri (Çalıkoğlu & Kahveci, 2015), bilimin doğası (Gilbert & Newberry, 2007), kritik ve yaratıcı düşünme becerileri ile 21. Yüzyıl becerileri (Kaplan, 2012), ve öğrencilerin fen bilimlerine karşı motivasyonlarını artırmak (Çalıkoğlu & Kahveci, 2015; Newman & Hubner, 2012) gibi becerilerin kazandırılması gereklidir. Bu açıdan öğretmenin zenginleştirilmiş program bilgisi incelendiğinde öğrencilerine bilginin yanında yukarıdaki becerileri de kazandırabileceği uygulamalar geliştirmesi gerekmektedir.

Öğrenci bilgisi

Bu bileşen dört alt bileşenden oluşmaktadır; (1) üstün yetenekli öğrencilerin özellikleri bilgisi, (2) konunun öğrenilmesi için gerekli bilgiler, (3) öğrencilerin zorlandıkları alanlar bilgisi ve (4) öğrencilerin alternatif kavramlar bilgisi.

Üstün yetenekli öğrencilerin özellikleri bilgisi. Bu bölüm öğretmenin üstün yetenekli öğrencilerin özellikleri hakkındaki fikirlerini içermektedir. Bu çalışmada üstün yetenekli öğrenciler aşağıdaki özellikleri sınıf ortamına yansıtmıştır. (1) öğrenciler yeni kavramları öğrenirken öğretmenin yaptığı açıklamaları kolay kolay kabul etmemektedir, (2) öğrenciler ders sırasında öğretmen veya arkadaşları ile tartışma ortamı oluşturma eğilimindedirler ve buda zaman kaybına yol açmaktadır. (3) Öğrenciler zor ve ilginç sorular sorma eğilimindedirler. (4) Öğrenciler sınıf ortamında yapılamayacak hedef ve davranışlar sergilemektedirler. (5) Öğrenciler meraklı ve sorgulayıcı özelliklerinden dolayı zenginleştirilmiş aktiviteleri daha da ileri düzeye taşımaktadırlar ve öğretmen bu daha da ileri düzey bilgileri öğrencilerine açıklamak zorunda kalmaktadır. (6) Öğrenciler ilgili konu ve kavramları hızlı ve kolay öğrenmektedirler. Bu yukarıda gözlenen öğrenci özellikleri alan yazında da karşımıza çıkmaktadır. Kolay kolay yeni bilgileri kabul etmeme (Stott & Hobden, 2016), zor ve ilginç sorular sorma (Miller, 2009; Park & Oliver, 2009), zenginleştirilmiş aktiviteleri irdeleme ve daha ileri düzey bilgilere ulaşma (Laine, Kuusisto, & Tirri, 2016; Stott & Hobden, 2016), hızlı ve kolay öğrenme (Gilman, 2008; Joffe, 2001; Laine vd., 2016; Manning, 2006; Miller, 2009; Park & Oliver, 2009; Taber, 2007).

Konunun öğrenilmesi için gerekli bilgiler. Öğrencilerin anlamlı öğrenmelerini sağlamak adına ön bilgilerinin ve becerilerinin tam olması gerekir. Etkili ve başarılı bir fen bilimleri öğretmeninin ise bu gereksinimleri iyi analiz edip bilmesi gerekir (Magnusson ve ark., 1999). Kavramsal öğretimi sağlamak adına çalışmaya katılan öğretmen öğrencilerinin bu ön bilgileri hakkında bilgi sahibi. PAB bileşenlerinden birisi olan öğretim programı bilgisi öğretmene bu noktada çok kolaylık sağlıyor ve öğretmen öğrencilerin bilmesi gereken ön bilgilerini değerlendirebiliyor. Örneğin iş ve enerji konusunu anlamlı bir şekilde öğretebilmek için öğrencilerin şu kavramları biliyor olması gerekir; kuvvet, net kuvvet, bileşke kuvvet ve iş. Bu tür ön bilgilerin sırası kavram öğretiminde önemlidir örneğin basit makineler kavramının öğretimi ondan sonra öğretilecek olan kavramların öğretiminde önemli rol oynar (Marulcu & Barbett, 2013).

Bu ön gereksinimler öğretmen tarafından ders planda bahsedildi ancak sınıf gözlemi ve öğretmenin sunumu sırasında bazı ön gereksinimler keşfedildi. Örneğin kütle ve yerçekimi arasındaki farkı bilmek, kuvvet ve yerçekiminin birimlerini bilmek gibi ya da dinamometre kullanabilme becerisi gibi öğrencilerde bilmeleri gereken eksik bilgilere rastlanmıştır. Bu eksik bilgiler ise ilgili konuların öğretimi sırasında öğrenme zorluğu oluşturmuştur. Ayrıca öğretmenin sunduğu zenginleştirme aktivitelerinin içeriğinde matematiksel işlemler mevcuttur ve bazı öğrenciler bu işlemleri yapmakta zorlanmaktadır.

Öğrencilerin zorlandıkları alanlar bilgisi. Fen kavramları soyut ve karışık bir özellik gösterdiği için bu kavramların öğretilmesi zordur (Ginn & Waters, 1995; Loughran ve ark., 2006). Özellikle fizik konuları diğer disiplinlere göre öğretmenler tarafından bu konuların öğretilmesinin daha zor olduğuna inanılır (Ahtee & Johnston, 2006; Johnston & Ahtee, 2006). Bu bağlamda katılımcı öğretmende alan yazınla aynı fikirdedir ve sınıf sunumları sırasında hem öğrenciler birçok öğrenme zorluğuyla karşılaşmış hem de öğretmen öğretme zorluklarıyla karşılaşmıştır.

Bu öğrenme zorlukları genellikle iki kaynaktan gelmektedir birincisi öğrencilerin ön bilgilerindeki eksiklik ve ikinci kaynak öğrenme zorluğu ise öğretmenin sunduğu ileri düzey zenginleştirilmiş aktiviteler. Eğer öğrencilerde ön bilgi eksiği var ise öğretmen bu eksiklikleri gidermeden hedeflenen davranışları kazandıramamaktadır. Bu yüzden öğretmen eksik bilgileri en kısa yoldan düz anlatım yöntemiyle açıklamaya çalışmakta ve öğrenciler tarafından yeni yeni ilginç ve zor sorulara maruz kalmaktadır. Bu zor ve ilginç sorular benzer şekilde zenginleştirme aktiviteleri uygulanırken de öğrenciler tarafından gelmektedir. Çünkü öğrencilerden bazıları ileri konuları ya anlamamakta ya da ilgili becerilere sahip olmamaktadır. Örneğin bileşke kuvvetin yaptığı iş, ya da içler dışlar çarpımı gerektiren matematiksel denklemler öğrenciler tarafından yapılamamaktadır. Bu tür uygulamalar öğrenciler için öğrenme zorluğu yaratmaktadır.

Öğrencilerin alternatif kavramlar bilgisi. Alan yazın incelendiğinde hem öğretmenlerde hem de öğrencilerde birçok fizik konularında kavram yanılgılarının olduğu görülür. Örneğin iş enerji konusunda (Avcı, Kara, & Karaca, 2012; Çoban, Aktamış, & Ergin, 2007; Kruger, 1990; Trumper, 1998; Yürümezoğlu, Ayaz, & Çökelez, 2009), basit makineler (Marulcu & Barnett, 2013) ve sürtünme kuvveti ve enerji (Atasoy & Akdeniz, 2007; Hançer, 2007; Hope & Townsend, 1983; Kaplan, Yılmazlar, & Çorapçıgil, 2014). Alternatif kavramlar ise öğrencilerin kavramlar hakkındaki doğru olmayan düşünce ve inanışlarından oluşur. Bu çalışmada öğretmenin öğrencilerde bulunan olası alternatif kavram bilgisi iki grupta incelenmiştir. Birinci grup bilgi öğretmenin farkında olduğu yani bildiği alternatif kavramlar veya kavram yanılgıları. Örneğin "iş günlük hayatta yapılan şeylerdir", "hız ve sürat aynı kavramlardır" ve "makineler elektronik araç-gereçler içerir". Diğer grup ise öğretmenin farkında olmadığı ve ders planı ve ön görüşmelerde belirtmeyip ders gözlem sırasında karşılaşılan alternatif kavramlardır. Örneğin "hızlı bir araç yavaş araçtan daha fazla kinetik enerjiye sahiptir", "daha yüksekteki bir nesne diğerine göre daha fazla potansiyel enerjiye sahiptir", "enerji kinetikten potansiyele doğru geçerken kaybolur". "merdivenler eğik düzlem değildir", "kütle ve ağırlık aynı şey değildir", "mekanik avantaj iş ve enerjiden elde edilir" ve "sürtünme kuvveti daima harekete ters yöndedir" şeklinde öğrenciler birçok alternatif kavramlara sahiptir. Bu alternatif kavramlar birçok öğrenme zorluğu oluşturmuştur.

Öğretmenin farkında olmadığı kategorideki alternatif kavramlar diğer gruptaki kavramlara göre daha fazla olduğu için öğretmenin bu alt bileşen hakkındaki bilgisinin zayıf olduğu çıkarımına varabiliriz. Ancak ilgili konuların öğretimi sırasında öğretmen birçok alternatif kavramla karşılaşmış ve bunları giderme yoluna gitmiştir. Bu yüzden öğretmenin bu alt bileşen hakkında PAB'ı gelişmiştir diyebiliriz çünkü PAB gelişiminde birincil kaynak öğrencilerin alternatif kavramları ve bu kavramları gidermek için gösterilen çabadır (Park & Oliver, 2008).

Öğretim strateji bilgisi

Bu PAB bileşeni iki alt boyutta incelenir konuya özlü öğretim stratejileri ve alana özgü (disiplin temelli) öğretim stratejileri. Araştırma-sorgulamaya dayalı öğretim, 5E yöntemi, kavram değişimi gibi alana özgü stratejiler bu çalışmada ne planlama aşamasında nede uygulama aşamasında öğretmen tarafından ele alınmıştır. Bu durum Türkiye'deki çalışmalarda sıkça karşılaşılan bir durumdur (Akın,2017; Aydın, 2012; Ekiz Kıran, 2016).

İş ve enerji konusunda, konuya özgü stratejilere baktığımızda öğretmen derse soru cevap tekniğini kullanarak başlıyor ve öğrencilerin ön bilgilerini kontrol ediyor ya da alternatif kavramlarını tespit etmeye çalışıyor. Eğer öğretmen herhangi bir eksik bilgi ya da alternatif kavramla karşılaşırsa klasik sunum tekniklerini kullanarak eksiklikleri gidermeye çalışıyor. Çünkü öğretmen sınırlı bir zamanda beklenmedik bir durumu düzeltmenin en kolay yolunun düz anlatım olduğuna inanıyor. Öğretmen daha sonra hedeflenen kazanımları öğretmek için PowerPoint sunumları ile görseller sunuyor, gösteri deneyleri yapıyor, ya da modeller kullanılarak klasik öğretim stratejileri zenginleştiriliyor. Bu stratejilerin kullanımı alt konular arasında değişiklik göstermektedir. Alan yazında da öğrencilerden gelen geri bildirimler doğrultusunda öğretmenler sunum stratejilerini yeniden yapılandırmaktadır (Lee & Luft, 2008).

Bu çalışmada düz anlatım yöntemi genel kullanımından farklılaşıyor çünkü üstün yetenekli öğrenciler özelliklerinden dolayı derslerde aktif role oynayarak öğrenci merkezli bir ortam oluşturuyorlar. Alan yazın ise bu durumu desteklemektedir (Miller, 2009; Newman & Huber, 2012; Park & Oliver, 2009) üstün yetenekli öğrenciler tartışma ortamı yarattıkları için aktif öğrencilerdir ve düz anlatımdan sıkılırlar (Samardzija & Peterson, 2015).

Katılımcı öğretmen ilgili yeni kavramları öğrettikten sonra öğrencilere önemli bölümler hakkında not aldırıyor ve sonrada değerlendirme kısmı ile ders tamamlanıyor.

Basit makineler ve sürtünme kuvveti konularının öğretimi sırasında ise yukarıda anlatılan konuya özgü öğretim stratejileri genel anlamda benzerlik gösteriyor. Sadece tümevarım laboratuvar uygulaması hem basit makineler konusunda, kaldıraçları anlatırken uygulanıyor hem de sürtünme kuvvetinde uygulanıyor. Öğrenci merkezli bir uygulama ile öğrenciler hedeflenen kavramları keşfedebildiler. Farklı olarak basit makineler konusunda makaralar, palangalar ve kaldıraçlar hakkında öğretmen ileri düzeyde karmaşık problemler sundu ve dişli-çarkların öğretimi sırasında ise model kullanmıştır. Ayrıca öğretmen kaldıraçlar ile çıkrık arasında analoji kurularak çıkrık konusu daha etkili anlatmıştır.

Değerlendirme bilgisi

Bu çalışmada öğretmen değerlendirme olarak dersin başlangıcında öğrencilerinin ön bilgilerini kontrol etmek, alternatif kavramlarını tespit etmek veya eksik bilgilerini belirlemek amacıyla soru cevap yöntemi ile informal bir değerlendirme yapmaktadır. Ders süresince her bir öğrencisini yakından takip ederek onların kavramsal öğretim performanslarını kontrol altına almaktadır. Yani her bir öğrenciyle bireysel ilgilenmektedir ancak bu değerlendirme türü ise gözlem yoluyla yapıldığı için yine informal bir değerlendirme yaklaşımı benimsenmiştir. Dersin sonunda ise öğretmen öğrencilerin konu hakkında neler öğrendiklerini çoktan seçmeli testler, açık uçlu sorularla değerlendirmiştir. Öğretmen bu değerlendirme bilgi ve becerilerini tüm konular boyunca kullandığı için öğretmenin değerlendirme bilgisini alana özgü (disiplin temelli ya da özellikte) diyebiliriz. Alan yazında bu doğrultuda PAB'ın değerlendirme bilgisi bileşenini alana özgü olarak ele almaktadır (Aydın ve ark., 2014; Gess-Newsome, 2015; Üner, 2016).

PAB bileşenlerinin etkileşimleri sonuç ve tartışması

Bu bölümde öğretmenin kullanmış olduğu PAB bileşenlerinin etkileşimleri hem planlama aşamasında hem de uygulama aşamasında önce özetlenerek sonra da alan yazınla tartışılarak açıklanmıştır.

Planlama aşamasındaki etkileşimlere bakıldığında üç bileşen STO (fen oryantasyonu), KoC (program bilgisi) ve KoL (öğrenci bilgisi) etkileşimleri başlatan bileşenler olarak karşımıza çıkmaktadır. Dersin başlangıç kısmında STO bileşeni etkin rol oynamaktadır çünkü öğretmen hedef ve amaçlarını belirtmektedir. Daha sonraki süreçte zenginleştirilmiş aktivitelerin planlanması yapıldığı için KoC öğretmen tarafından kullanılmaktadır. Son olarak öğretmen öğrencilerde var olan alternatif kavramlar üzerine odaklanmış ve bunları gidermek için olası yöntemler geliştirmiştir. Bu süreçte KoL etkileşimleri başlatan bir bileşendir. KoL ve KoC öğretmenin oryantasyonunu etkilemektedir. Çünkü üstün yetenekli öğrenciler zenginleştirilmiş aktivitelere ihtiyaç duymakta ve öğretmenin amaç ve hedeflerini şekillenmektedir. Diğer yandan KoIS (öğretim stratejileri bilgisi) ve KoA (değerlendirme bilgisi) bileşenleri planlama aşamasında ikincil etkileşen bileşenler olarak karşımıza çıkmaktadır ve öğretmen planlama sürecinin ikinci bölümünde bu bileşenleri sıklıkla kullanmaktadır. Çünkü öğretmen öğrencilerin eksik bilgileri, alternatif kavramları veya öğrenme zorluklarını belirli öğretim stratejilerini kullanarak gidermeyi planlamaktadır. Planlama aşamasının son bölümü ise ilgili konuların değerlendirilmesiyle ilgili olduğu için KoA sıklıkla kullanılan bileşendir. Sonuç olarak öğretmenin planlama aşamasının ikinci bölümünü etkileyen KoIS ve KoA bileşenleridir.

Öğretmenin uygulama aşamasında kullandığı bileşenlerin etkileşimine bakıldığında öğretmenin sunumunu dört farklı bölüme ayırabiliriz. İlk bölümde KoIS etkileşimleri başlatan bileşen olarak karşımıza çıkmakta ve öğrencilerin ön bilgileri ya da alternatif kavramları kontrol edildiği için KoA ile etkileşim halindedir. Daha sonrasında öğretmen ilgili kavram veya konunun öğretimine geçmekte ve KoIS ile STO etkileşime girmektedir. Bu süreçte bazı öğrenme zorlukları ortaya çıkmakta ve öğretmen farklı stratejiler ile bu zorlukları gidermektedir. Bu durumda KoIS ile KoL etkileşimdedir. Son olarak KoIS ile KoC etkileşimdedir ve öğrencilerde anlamlı öğrenme gerçekleşmesi için öğretmen zenginleştirilmiş aktivitelerden faydalanarak daha somut örnek ve açıklamalar sunmaktadır. Bu ilk öğrenme bölümü tüm konuların öğretilmesinde kullanılmaktadır. Ancak basit içerikli alt konular örneğin basit makineler kavramı, enerjinin korunumu, dişliler veya çarklar konuları yalnızca bu ilk öğrenme bölümünden oluşmaktadır. İlk bölümden sonraki bölümler daha çok karışık yapılı konularda ortaya çıkmaktadır örneğin, iş ve enerji, kinetik ve potansiyel enerji, makaralar, kaldıraçlar gibi.

İkinci öğrenme bölümünde ise KoL ile KoC etkileşimi görülmektedir. Üstün yetenekli öğrencilerin özelliklerinden dolayı öğretmen zenginleştirilmiş aktiviteler sunmak durumundadır. Çünkü normal öğretim programı yeterli olmamaktadır. Bunun yanında öğrenciler lise konularını sorgulamakta ve öğretmen bu konu ve uygulamaları kısaca açıklamak zorunda kalmaktadır. Tüm bu üst düzey kavram ve uygulamalar zenginleştirilmiş aktivite olarak uygulanmaktadır.

Üçüncü öğretim bölümünde ise zenginleştirilmiş aktiviteler öğrenme zorluğu yaratmaktadır. Çünkü ileri düzey konu ve uygulamalar ekstra ön bilgi ve beceri gerektirmektedir. Örneğin, bileşke kuvvetin yaptığı işi anlatmak için öğrencilerin trigonometri bilgilerinin olması gerekir, ya da laboratuvar uygulamalarında dinamometrenin nasıl kullanıldığı ve birimlerinin ne olduğu öğrenciler tarafından bilinmelidir. Tüm bu uygulamalar öğrencilerde öğrenme zorluğu meydana getirmektedir. Bu durumda KoC ile KoL etkileşim halindedir.

Son öğretim bölümünde ise değerlendirme ön plandadır. Öğretmen öğrencilerin performanslarını kavramsal öğretim olarak çoktan seçmeli testler, açık uçlu sorular ya da örnek sorularla belirlemeye çalışmaktadır. Bu durumda KoIS ve KoA etkileşime girmektedir.

Yukarıdaki genel özetten sonra alan yazında var olan etkileşim sonuçları ile bu çalışmanın bulguları birkaç faktörle tartışılmıştır. İlk faktör etkileşim haritaları konuya özgü bir özellik gösterir ve konudan konuya değişmektedir. Çünkü hem planlama hem de uygulama haritalarındaki ikili, üçlü, dörtlü ya da daha fazla etkileşimler mevcuttur ve çeşitlilik göstermektedir. Bu bulgu alan yazındaki konuya özgü PAB çalışma sonuçlarıyla paraleldir (Akın, 2017; Aydın & Boz, 2013; Park & Chen, 2012).

İkinci faktör ise STO etkisidir. Alan yazında STO diğer bileşenleri etkilemekte ve şekillendirmektedir (Boesdorfer & Lorsbach, 2014; Friedrichsen & Dana; 2005; Friedrichsen ve ark., 2009; Friedrichsen ve ark., 2011; Grossman, 1990; Magnusson ve ark., 1999). Bu çalışma bulgularında ise özellikle planlama sürecinde STO tüm bileşenlerle etkileşim halindedir ve tüm bileşenleri etkilemektedir diyebiliriz. Diğer yandan öğretmenin STO üstün yetenekli öğrencilerin özelliklerinden etkilenmektedir. Öğretmen ders planlarına ekstra amaç ve hedef eklemekte ve ders sunumları klasik oryantasyondan az ya da çok reform temelli oryantasyonlara doğru kaymaktadır.

Üçüncü faktör ise bileşenlerin etkileşim sayılarıdır. Bazı çalışmalar KoA bileşeninin etkisini çalışmalarında bulamamışlardır (Friedrichsen ve ark., 2009; Kaya, 2009). Bazı çalışmalarda ise KoA diğer bileşenlerle az etkileşime girmektedir (Aydın & Boz, 2013; Aydın ve ark., 2015; Padilla & van-Driel, 2011). Fakat Park ve Chen (2012) çalışmasında KoA etkisi görülmektedir çünkü öğretmenler informal değerlendirme tekniklerini sıklıkla kullanmaktadır. Bu çalışmada da informal değerlendirme etkisi haritalarda açık şekilde bellidir. Yani bu çalışmada öğretmen KoA bileşenini hem planlama hem de uygulama aşamasında sıklıkla kullanmıştır.

Diğer bileşenlerin etkileşim sayılarına bakıldığında uygulama haritalarında KoIS hem etkileşimi başlatan hem de sıklıkla kullanılan bir bileşenidir. Çünkü ders sırasında öğretmen her daim bir öğretim davranışı sergilemektedir bunu konuşarak, gösteriler yaparak, açıklamalar yaparak, sorular sorarak, ya da rehberlik ederek KoIS bileşenini kullanmaktadır. Diğer yandan KoL ise planlama sürecinde en çok etkileşimde olan bileşendir. Bu durum Akın (2017) çalışmasında da bulunmuştur KoIS, KoC ve KoL bileşenleri diğerleriyle etkileşimde olan merkezi bileşenlerdir. Aydın ve Boz (2013) çalışmasında ise KoL ve KoIS en çok etkileşimde olan bileşenlerdir.

Bu çalışmadaki PAB bileşenlerinin etkileşimlerinin son faktörü ise etkileşimlerde bulunan güçlük derecesi ya da karmaşıklıktır. Bu çalışmada kullanılan haritala tekniği bu etkileşimlerin güçlük derecesini tam yansıtmaktadır. Haritalarda üçlü, dörtlü veya daha fazla etkileşimde bulunan bileşenler vardır. Bazı çalışmalar bu etkileşimleri sadece tek yönlü ya da iki yönlü olarak iki bileşen arasında gösterir (Aydın, 2012; Henze ve ark., 2008). Bu çalışmada ise etkileşimlerin güçlükleri bileşen sayısına göre artmaktadır. Örneğin KoL-KoA, KoIS-KoA gibi ikili etkileşimler basit düzey etkileşimleri gösterirken KoL-KoIS-KoA veya KoL-KoIS-KoA-KoIS-KoA-KoIS gibi üçlü veya daha fazla olan etkileşimler ise daha karışık ve zor bir pedagojik davranışa denk gelmektedir.

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YAZARIN

Soyadı : ÇAYLAK
Adı : Burak
Bölümü : İlköğretim

TEZİN ADI (İngilizce) : EXAMINATION OF TOPIC-SPECIFIC NATURE OF PEDAGOGICAL CONTENT KNOWLEDGE: A CASE OF SCIENCE TEACHER OF GIFTED STUDENTS

TEZİN TÜRÜ : Yüksek Lisans ☐ Doktora ■

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