ASSESSMENT OF HIGH SCHOOL PHYSICS TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE RELATED TO THE TEACHING OF ELECTRICITY

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ABSTRACT

ASSESSMENT OF HIGH SCHOOL PHYSICS TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE RELATED TO THE TEACHING OF ELECTRICITY

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The main purpose of this study is to assess pedagogical content knowledge (PCK) of in-service physics teachers about electricity topic in high school level by developing a paper-and-pencil instrument consisting of open-ended items. The instrument was developed with four different implementations by administration to the 278 in-service physics teachers.

An exploratory and confirmatory factor analysis including only PCK items was conducted in validation processes. The relations among teachers' job satisfaction levels, perceived self-efficacy levels, years of teaching experience and specific experiences, attendance to in-service training seminars related to physics teaching programs and teachers' PCK were also analyzed by a confirmatory structural equation modeling study in validation of test scores. SPSS and AMOS programs were used in the analyses.

Results of the study showed that teachers' perceived self-efficacy level, attendance to in-service training seminars and specific experiences were significant predictors of their PCK. Teachers' years of teaching experience and job satisfaction level were not significant predictors of their PCK. Inter-rater reliability scores were calculated as 0.86 and 78% for scoring and coding of the participant teachers' responses respectively. Results also showed that there are many Turkish physics teachers whose PCK scores regarding students' learning difficulties and misconceptions are below the average and participants mostly prefer to implement direct instruction in their classrooms as the instructional strategy.

Keywords: Physics teacher, pedagogical content knowledge, assessment of teacher knowledge, job satisfaction, self-efficacy, electricity

ÖZ

FİZİK ÖĞRETMENLERİNİN ELEKTRİK KONUSUNUN ÖĞRETİMİNE YÖNELİK PEDAGOJİK ALAN BİLGİLERİNİN ÖLÇÜLMESİ

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Bu çalışmanın amacı açık-uçlu sorular içeren bir ölçüm aracı geliştirerek fizik öğretmenlerinin elektrik konusuna yönelik pedagojik alan bilgilerini (PAB) ölçmektir. Ölçüm aracı 278 fizik öğretmeninin katılımıyla dört farklı uygulamaya dayanılarak geliştirilmiştir.

Ölçme sonuçlarının geçerlik denetim sürecinde PAB maddelerine yönelik açımlayıcı ve doğrulayıcı faktör analizi uygulanmıştır. Öğretmenlerin mesleki doyum seviyeleri, öz-yeterlik algı seviyeleri, mesleki deneyimleri ve özel deneyimleri, fizik öğretim programlarına yönelik hizmet-içi eğitimlere katılımları ve PAB'ları arasındaki ilişki doğrulayıcı yapısal eşitlik modellemesi ile analiz edilmiş ve ölçüm sonuçlarının geçerliliğine katkı sağlamıştır. Analizlerde SPSS ve AMOS programları kullanılmıştır.

Çalışmanın sonuçları öğretmenlerin öz-yeterlik algı seviyeleri, hizmet-içi eğitim katılımı ve özel deneyimlerinin, PAB'larını anlamlı olarak yordayan bileşenler olduğunu göstermiştir. Öğretmenlerin genel deneyimleri ve mesleki doyum seviyeleri PAB kalitesinin anlamlı yordayıcıları olarak bulunmamıştır. Katılımcıların cevaplarının puanlandırılmasına ve kodlanmasına yönelik değerlendirici güvenirliği değerleri sırası ile 0.86 ve %78 olarak hesaplanmıştır. Çalışma sonuçları birçok fizik öğretmenimizin öğrencilerin öğrenme zorlukları ve kavram yanılgılarına yönelik PAB puanlarının ortalamanın altında olduğunu ve katılımcıların sınıf içi uygulamalarında öğretim stratejisi olarak daha çok doğrudan anlatımı tercih ettiklerini de göstermiştir.

Anahtar Kelimeler: Fizik öğretmeni, pedagojik alan bilgisi, öğretmen bilgisini ölçme, mesleki doyum, öz-yeterlik, elektrik

To My Wife Nermin BAHÇİVAN,
it is impossible to ignore her support

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LIST OF ABBREVIATIONS

PCK	: Pedagogical Content Knowledge
PCKg	: Pedagogical Content Knowing
SMK	: Subject Matter Knowledge
CK	: Content Knowledge
C-P	: Content–Specific Pedagogical Knowledge
CoRe	: Content Representation
PaP-eR	: Professional experience Repertoires
PECKI	: Pedagogical Electricity Content Knowledge Instrument
KSUE	: Knowledge of Students' Understanding of Electricity
KIS	: Knowledge of Instructional Strategies
PSE	: Perceived Self-Efficacy
PSEI	: Perceived Self-Efficacy Instrument
JS	: Job Satisfaction
JSI	: Job Satisfaction Instrument
CFA	: Confirmatory Factor Analysis
SEM	: Structural Equation Modeling
SPSS	: Statistical Package for the Social Sciences
AMOS	: Analysis of Moment Structures
RMSEA	: Root Mean Square Error of Approximation
TLI	: Tucker-Lewis Index
GFI	: Goodness-of-Fit Index
CFI	: Comparative Fit Index

CHAPTER 1

INTRODUCTION

Even though many research studies in education directly focus on the measurement and evaluation of students' achievement and learning outcomes, these attempts cannot portray classroom learning environments comprehensively (Fraser, 2003). Teacher is one of the most vital components of a classroom learning environment since his/her practice affects students' achievement in and meaningful understanding of a subject (Abell, 2007). By selecting (in)appropriate teaching strategies and methodologies, teachers shape the classroom learning environments, and therefore affects conceptual understanding of the students (Heck, 2009; Linney, 1989). In this regard, it is important to determine qualifications that contribute to teachers' instructional practices and to evaluate teachers on these qualifications (Fabiano, 1999). Efforts regarding determination and evaluation of teacher qualifications also support the applicability of educational reforms such as curriculum changes (MoNE, 2008; Tutkun & Aksoyalp, 2010).

The gap between what a (physics) teacher wants to teach and what students learn has been a fundamental issue in (physics) education (McDermott, 1991). This gap motivates education researchers to identify teacher qualifications for different subjects including science such as physics, chemistry, etc… Considering necessity of this identification, Ministry of National Education (MoNE) in Turkey has started the studies for determination of teacher qualifications since 2002. Determining teacher qualifications of elementary and high school teachers in all subjects started in 2004 (MoNE, 2008) and completed in 2011.

Dewey (1902), to the best of my knowledge, for the first time stated the main differences between a scientist's and a teacher's role and knowledge as regards subject matter. However, this comparison had not been magnified for years. Ausubel (1968) stated that "the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (p. iv). However, Ausubel's statements did not also draw the education researchers' attention on teacher knowledge. Research on teacher knowledge has been mainly conducted in only last three decades. Elbaz (1983) referred teacher knowledge as 'practical knowledge' which was supporting teachers to teach effectively in different contexts since this knowledge includes students' learning interests, abilities and difficulties together with different types of instructional techniques. According to Elbaz (1983) practical knowledge is a bridge between the curriculum and actual student learning.

In his famous research study, Shulman (1986) gave some examples to teacher competency tests focusing mostly on the subject matter to be taught in assessment of teachers and/or teacher candidates. According to him, these tests were pointing out a missing paradigm which was about transformation of subject matter into content of instruction. He named this knowledge domain as pedagogical content knowledge (PCK). PCK is topic-specific and is formed by 'the blending of content and pedagogy' (Shulman, 1987). The main differences between PCK and 'practical knowledge' are that the former is topic-specific and implying the missing paradigm. Following these studies, Wilson, Shulman and Richert (1987) defined teacher knowledge base as "the body of understanding, knowledge, skills, and dispositions that a teacher needs to perform effectively in a given teaching situation" (p.106). Based on the studies about teacher knowledge, we can state that teacher knowledge base is an umbrella term including knowledge domains required for effective teaching. In subsequent years, researchers have included PCK in their descriptions of knowledge base of a teacher (see for example, Carlsen, 1999; Grossman, 1990; Turner-Bisset, 1999).

Research studies describing structure of PCK has accelerated since Shulman's definition of this concept (Abell, 2008; Cochran, DeRuiter & King, 1993; Turner-Bisset, 1999; van der Valk & Broekman, 1999; Veal & MaKinster, 1999). These descriptive studies clarified that PCK has some other components such as knowledge of students' understanding, instructional strategies, curriculum, assessment, and so forth. Even if these components were also defined as domains of teacher knowledge base, PCK was constituted by (integration or transformation of) these knowledge domains in many research studies (see for example, Grossman, 1990; Magnusson, Krajcik & Borko, 1999, Tamir, 1988; Wilson et al., 1987). Most of the descriptive studies modeling PCK represented teachers' knowledge of students' understanding and instructional strategies as the constituent components.

The importance of PCK arises from the fact that it is affected by teachers' beliefs and is effective on their classroom implementations and decisions (van Driel, Beijaard & Verloop, 2001). Teacher implementations and decisions in a classroom can sometimes be sources of student misconceptions (Halim & Meerah, 2002; Yumuşak, 2008). In a science classroom, we cannot say that a particular teaching strategy is more appropriate than others. Instead, we prefer to state that a teaching strategy is appropriate when it is needed in accordance with students' learning and cognitive abilities (Schroeder, 2007). Many researchers stressed that teachers' PCK have visible effects on their implementations, and decisions regarding instructional strategies (Grossman, 1990; Magnusson et al., 1999). Moreover, a group of researchers in mathematics education represented some evidences that teachers' PCK were effective on their students' achievements (Hill, Rowan & Ball, 2005).

PCK has been accepted as one of the fundamental concepts in teacher education literature for three decades. However, descriptive studies related to PCK have led to emergence of new labels for the already existing components of PCK (Abell, 2007; Appleton & Kindth, 1999; Friedrichsen, 2008). For example while Cochran et al. (1993) named one of the PCK components as 'knowledge of students,' Magnusson et al. (1999) named the same component as 'knowledge of students' understanding' of science in their PCK models. In this respect, research on PCK in science education should focus on teachers' classroom implementations of different topics and studies about assessment of teachers' PCK instead of descriptive studies (Abell, 2008; van Driel et al., 1998).

In political arena, assessment of teachers' PCK has gained much importance for the last ten years in both international and national levels. National Council for Accreditation of Teacher Education (NCATE) in the US included PCK as a standard for assessment of teacher candidates' performances (NCATE, 2002). In national level, MoNE published teacher qualifications, including PCK, specified for each subject areas in both of elementary and high school education. These standards and qualifications force researchers to develop ways for assessment teachers' PCK. Today many researchers from different subject areas try to develop ways for assessing teachers' PCK. Assessment of teachers' PCK gives feedback to teacher education and teacher professional development programs in terms of how pre-service and in-service teachers' knowledge should be supported (Hill, Schilling & Ball, 2004; Lange, Kleickmann & Möller, 2009; Rohaan, Taconis & Jochems, 2009). Assessment tools developed in such studies provide guidance for teacher certification exams to assess teachers' knowledge base (Hill et al., 2004; Rohaan et al., 2009).

Baxter and Lederman (1999) stated that PCK assessment studies generally use qualitative research designs, especially case studies. In these studies, researchers generally use classroom observations, interviews and lesson plans as data sources regarding assessment. These designs produced useful hints for researchers about teachers' PCK structures rather than assessment (Loughran et al., 2001). However, because of the nature of these research designs and their purposes, methods used to assess teachers' PCK do not lend themselves for large-scale assessment. Because such methods require long-term observations of teachers' classroom practices (Kagan, 1990, as cited in Baxter & Lederman, 1999; Loughran, Mulhall & Berry, 2004; Rohaan et al., 2009; Rollnick et al., 2008). Although these designs display teacher knowledge in greater detail, they are time-consuming, include low number of teacher participants and need high-quantity investment for assessment of teachers' PCK (Baxter & Lederman, 1999; Kromrey & Renfrow, 1991). In this regard, it seems that qualitative studies in do not make conspicuous contributions to research area in terms of assessment of teachers' PCK, although they have a potential to represent a more comprehensive picture of a teacher's PCK.

On the other hand, limited number of quantitative designs for assessing teachers' PCK use paper-and-pencil tests which consist of multiple-choice and/or open-ended items. Researchers using these designs have struggled in construction of test items due to the lack of a standard for teaching a particular subject or a topic within that subject (Carlson, 1990; Kromrey & Renfrow, 1991; Rohaan et al., 2009). Researchers who utilized quantitative designs generally used different types of scenarios in items, since scenarios give them a chance for representing classroom contexts. Additionally, teachers mostly avoid assessment of their knowledge; however, scenario utilization in items decreases teachers' reluctance in such tasks (Hill et al., 2004; Krauss et al., 2008; Kromrey & Renfrow, 1991).

In science and technology education, some researchers, albeit limited in number, constructed instruments for assessment of teachers' PCK (Lange et al., 2009; Rohaan et al., 2009). However, their approaches, as some of them have themselves pointed out, have some issues in terms of reliability and/or validity. On the other hand, mathematics educators seemed to find ways for assessing PCK by using paper-and-pencil tests (Hill et al., 2008; Hill et al., 2004; Krauss et al., 2008; Manizade, 2006). They could assess PCK directly instead of using proxy measures which can be classified as number of courses taken by teachers during their pre-service education, subject-matter competence, teaching experience and cognitive abilities (Davis, 2003; Gess-Newsome, 1999a; Hill, Rowan & Ball, 2005; Wilson et al., 1987). In addition, their assessment approaches formed ways for possibility of large-scale assessments of mathematics teachers' PCK. Existing literature pointed out that not only physics education area but also all the subject areas need instruments enabling large-scale assessment of high school physics teachers.

As mentioned previously, PCK is a multidimensional construct. Therefore, rather than trying to assess all components of teachers' PCK, it is more feasible to concentrate on only a small number of components. In this study, developing

Pedagogical Electricity Content Knowledge Instrument (PECKI), we set out to investigate PCK in two dimensions: namely 'knowledge of students' understanding' (KSU) and 'knowledge of instructional strategies' (KIS). First dimension focused on physics teachers' knowledge about student preconceptions, learning difficulties and misconceptions about electricity topic. Second dimension provided evidence regarding which type of instructional strategies were mostly being used by high school physics teachers for overcoming the students' learning difficulties and misconceptions in electricity. The reason for selecting these components of PCK was the general acceptance of these in different conceptualizations by different researchers.

Considering the topic-specific nature of PCK, I decided to focus on topics related to electricity in physics to assess teachers' PCK, since it is not feasible to focus on all of the topics. Charging, electric fields, simple circuits, electric potential, and electric energy and power were determined as the focused concepts in electricity title. As a plethora of research studies have shown, students possess many misconceptions related to physics. Electricity presents students with many difficulties which sometimes results in misconceptions, even after physics instruction (Sencar & Eryilmaz, 2004). Abstract nature of the concepts in electricity causes that students have different types of learning difficulties and misconceptions in this domain of physics. In this regard, it is important to portray the physics teachers' knowledge about their students' learning difficulties and misconceptions, since it is crucial for a teacher to be knowledgeable about student understanding for an effective instruction.

In our assessment, we conducted a structural equation modeling study on the data as a part of validation processes. In this regard, we, based on the literature, needed to explore relationship of high school physics teachers' PCK with some other variables such as teachers' years of teaching experience, specific experiences, perceived self-efficacy (PSE) levels, job satisfaction (JS) levels and the number of in-service trainings related to physics teaching programs attended.

Many researchers asserted that PCK develops with classroom practice and teaching experience (Cochran et al., 1993; Crawford, 1999; Holt-Reynolds, 2000;

Morine-Dershimer & Kent, 1999; Veal, Tippins & Bell, 1999 among others). Some other researchers clarified that teachers' reflections in/on their practice had more critical value for PCK development than magnitude of professional experience. If teaching experience creates chances for teachers to be active and reflective on their implementations, then it contributes to their PCK development (Abd-El-Khalick, 2006; Park & Oliver, 2007). Therefore, year of teaching experience could not be accepted as an immediate predictor of PCK; however, this situation is still a controversial issue in physics education literature.

Teachers' beliefs affect their decisions in classroom (Pajares, 1992; Park & Oliver, 2007), and hence their PCK structures (Gess-Newsome, 1999a; Magnusson et al., 1999; Tobin & McRobbie, 1999; van Driel et al., 2001). As a critical part of teachers' beliefs self-efficacy includes beliefs of teachers in their capability affecting students' learning (Gibson & Dembo, 1984; Swackhamer et al., 2009). In this regard, teachers' self-efficacy beliefs have an effect on their instructional decisions, motivations, actions and performances (Caprara et al., 2003). Some studies showed that there is a relationship between teachers' PCK and their self-efficacy beliefs (Swackhamer et al., 2009; Yoon et al., 2006).

Moreover, high levels of teacher job satisfaction (JS) also affect teachers' instructional practices in classrooms and may have a positive effect on their students' achievements similar to self-efficacy beliefs and PCK (Caprara et al., 2003; Viel-Ruma et al., 2010). Van der Heijden and Brinkman (2001) found that employees' JS level can positively predict their professional knowledge levels. Additionally, deficiency in PCK may cause a decrease in teachers' JS level (Azar & Henden, 2003). In this respect, we thought that there should be statistically significant relations between teachers' PCK and JS level.

Furthermore, some researchers in this area included curricular knowledge of teachers as a component of PCK in their models (Grossman, 1990; Loghran et al., 2001; Magnusson et al., 1999; Tamir, 1988). According to integrative model of PCK, each component develops independently from each other (Gess-Newsome, 1999b). On the other hand, some researchers believe that in-service training seminars conducted to develop teachers' curricular knowledge may have a positive direct effect on teachers' PCK, since these programs have also a potential to increase teachers' qualifications in other dimensions of PCK in accordance with the transformative model (Gess-Newsome, 1999b, Magnusson et al., 1999, Nilsson, 2008).

Consequently, the purpose of my study is to assess high school physics teachers' knowledge of students' understanding of electricity and knowledge of instructional strategies related to teaching electricity by developing a paper-and-pencil instrument consisting of open-ended items. In doing so, we focused on Turkish high school physics teachers' knowledge regarding their students' preconceptions, learning difficulties and misconceptions, and the type of instructional strategies they used for overcoming student difficulties and misconceptions in electricity. In validation processes, we also provided evidence regarding the relationship of high school physics teachers' PCK and their years of teaching experience, specific experiences, PSE levels, JS levels, and the number of in-service trainings related to physics teaching programs attended.

1.1 Research Problems

There are three main research problems to be investigated in this study. These research problems and the research hypotheses of the first research problem prepared to collect evidence for the validation purposes were presented below:

The first research problem of my study was to establish acceptable validity and reliability estimates for an instrument developed to measure knowledge of students' understanding of electricity and knowledge of instructional strategies component of high school physics teachers' PCK related to the teaching of electricity. The research hypotheses are:

1) High school physics teachers' years of teaching experience have a positive, direct effect on their PCK.
2) High school physics teachers' specific experiences have a positive, direct effect on their PCK.

3) High school physics teachers' PSE level has a positive, direct and indirect effect on their PCK.
4) High school physics teachers' JS level has a positive, direct effect on their PCK.
5) High school physics teachers' attendance to in-service training seminars on the physics teaching programs has a positive, direct effect on their PCK.

The second research problem is related to the assessment of high school physics teachers' knowledge about students' pre-instructional thinking and misconceptions in electricity. The research question related to this problem is formulated as:

> What is the level of high school physics teachers' knowledge about students' pre-instructional thinking and misconceptions in electricity?

The third research problem is also related to the assessment of teachers' PCK, but this time on the component of teachers' knowledge of instructional strategies related to the teaching of electricity. The research question related to this problem is formulated as:

> What are the teaching strategies implemented by high school physics teachers to overcome student learning difficulties and misconceptions in teaching of electricity?

1.2 Statistical Research Hypotheses

In this section of the study, research hypotheses, constructed to collect evidence regarding the construct-related validity of the instrument, were also stated in statistical form. Therefore, we stated a null and an alternative hypothesis for each of research hypothesis presented above, respectively.

H_{01}: There is no positive and direct relationship between high school physics teachers' years of teaching experience and PCK scores.

H_1: There is a positive and direct relationship between high school physics teachers' years of teaching experience and PCK scores.

H_{02}: There is no positive and direct relationship between high school physics teachers' specific experiences and PCK scores.

H_2: There is a positive and direct relationship between high school physics teachers' specific experiences and PCK scores.

H_{03}: There is no positive, direct and indirect relationship between high school physics teachers' PSE and PCK scores.

H_3: There is a positive, direct and indirect relationship between high school physics teachers' PSE and PCK scores.

H_{04}: There is no positive and direct relationship between high school physics teachers' JS and PCK scores.

H_4: There is a positive and direct relationship between high school physics teachers' JS and PCK scores.

H_{05}: There is no positive and direct relationship between high school physics teachers' attendance to in-service training seminars on the physics teaching programs and PCK scores.

H_5: There is a positive and direct relationship between high school physics teachers' attendance to in-service training seminars on the physics teaching programs and PCK scores.

1.3 Significance of the Study

My study contributes to physics education literature in several ways. Firstly, there is a need for valid and reliable measures of PCK in physics education. This study measured physics teachers' PCK as direct as possible instead of benefiting from proxy measures. Turkish teacher candidates have been appointed to public schools by Personnel Selection Examination which does not include items assessing teacher candidates' PCK. Next, these types of instruments can be utilized in assessment of teacher qualifications. Turkey Ministry of National Education has determined teacher qualifications for all subjects, including physics. In this regard, my study can be considered as an encouraging attempt in assessment of PCK since it is providing an assessment tool for other researchers who seek to design similar instruments in other domains of physics and/or different aspects of PCK. Additionally, literature provides both empirical and theoretical evidences regarding that a teacher's PCK has relationship with some other variables. Physics education literature needs clarification of these relationships. Through its validation purposes, this study contributes to the literature, in context of Turkey, with its empirical results regarding the relationship between a high school physics teacher's PCK and his/her year of teaching experience, specific experiences, PSE level, JS level, in-service training attendance regarding physics teaching program.

Secondly, this study shows what Turkish high school physics teachers know about their students' pre-instructional thinking and misconceptions in electricity. Finally this study shows what type of teaching strategies are being used by Turkish high school physics teachers to overcome students' learning difficulties and misconceptions in electricity. Portraying teachers' knowledge in these areas has invaluable importance to the education researchers about how they should support the in-service and pre-service physics teachers.

1.4 Definitions of Important Terms

This section includes some important definitions of the terms as follow:

<u>Pedagogical Content Knowledge</u>: "special amalgam of content and pedagogy that is uniquely the providence of teachers, their own special form of professional understanding ... Pedagogical content knowledge ... identifies the distinctive bodies of knowledge for teaching. It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues arc organized, represented, and adapted to diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8). We assessed high school physics teachers' PCK with PECKI (see Appendix D).

Perceived Self-Efficacy: “Within organizations, … perceived self-efficacy (PSE) corresponds to the beliefs people hold about their capacity to meet successfully the opportunities and challenges associated with the various tasks characterizing their specific roles...” (Caprara et al., 2003, p. 821). We assessed high school physics teachers’ PSE level with PSE instrument (see Appendix E)

Job Satisfaction: “Job satisfaction (JS) is multidimensional psychological responses to one’s job. These responses have cognitive (evaluative), affective (or emotional), and behavioral components. JS refers to internal cognitive and affective states accessible by means of verbal—or other behavioral—and emotional responses” (Hulin & Judge, 2003, p. 255). We assessed high school physics teachers’ JS level with JS instrument (see Appendix E)

Misconception: In the Online Dictionary [OD] (2012), there are two definitions as below:

1. An erroneous conception,
2. Mistaken notion.

Hestenes, Wells and Swackhamer (1992) define misconception as “commonsense beliefs”.

Learning Difficulty: In the MacMillan Dictionary [MD] (2012), the definition is that a condition that prevents someone from learning basic skills or information at the same rate as other people.

Specific Experience: In this study, specific experience refers to whether the participant teachers experienced the student learning difficulties or misconceptions, represented in PECKI items, in their classroom context. The information regarding teachers’ specific experiences was collected with additional parts of PECKI, placed at the bottom of each item except for the last one.

Year of Teaching Experience: In this study, year of teaching experience refers to a high school physics teacher’s teaching experience in years. Participant teachers were requested to state their years of teaching experience on the beginning page of PECKI.

CHAPTER 2

LITERATURE REVIEW

In this chapter, I presented a review of literature in three sections: Definitions and common properties of PCK, assessment of PCK in mathematics, and science and technology education, teacher self-efficacy, job satisfaction (JS) and the relation of PCK with teachers' perceived self-efficacy (PSE) and JS. Finally, the summary of the literature review and some of our decisions taken by analyzing the literature were presented.

2.1 Definition and Common Properties of PCK

In 1986, Shulman pointed out a missing paradigm regarding learning environments with respect to teachers and called this paradigm as pedagogical content knowledge. He described PCK as

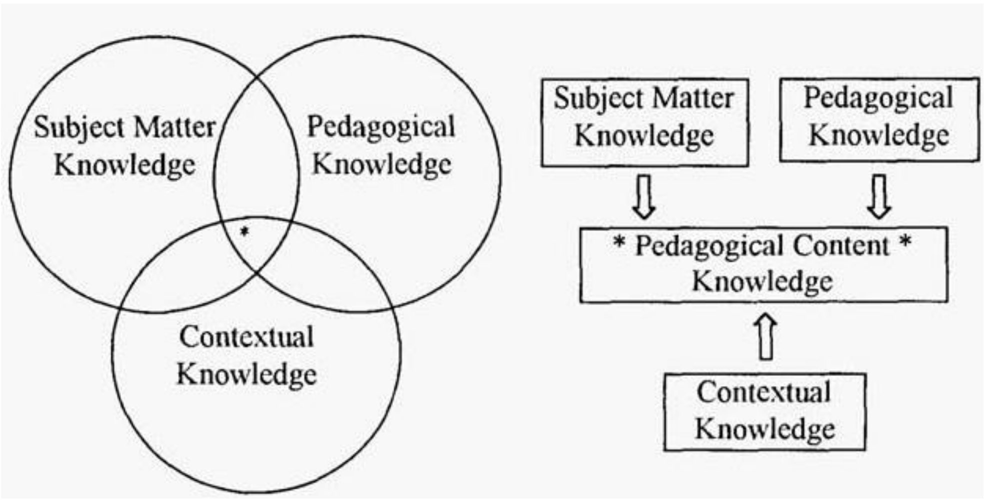
> …the most useful forms of representations of ideas, the most powerful analogies, illustrations, examples and demonstrations,…an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning (Shulman, 1986, p. 9).

One year later, Shulman (1987) declared some important characteristics of PCK by defining it as a unique knowledge of teachers to represent particular topics for instruction and bound with "diverse interests and abilities of learners" (Shulman, 1987, p. 8). Wilson et al.'s (1987) teacher knowledge base included seven components which are 'knowledge of subject matter', 'pedagogical content knowledge', 'knowledge of other content', 'knowledge of curriculum', ‘knowledge of learners’, ‘knowledge of educational aims’ and ‘general pedagogical knowledge’. In the containment of their study, PCK was mentioned as a new type of subject matter knowledge benefiting from other knowledge domains such as ‘Knowledge of the learner,’ ‘knowledge of the curriculum,’ ‘knowledge of the context,’ and ‘knowledge of pedagogy’. After Shulman’s clarification of PCK, some researchers extended its meaning and structure.

Existing studies show that researchers have reached a consensus partially related to PCK. Firstly, PCK includes knowledge of representations of subject-matter and knowledge of student conception (Grayson, 2004; Lee & Luft, 2008; Nilsson, 2008; van Driel et al., 1998). Multiple representations of a topic, which a teacher wants to teach, in accordance to the learners’ needs and/or contextual situation of a learning environment has a critical importance for PCK (Magnusson et al., 1999; Morine-Dershimer & Kent, 1999). Secondly, subject matter knowledge (SMK) has a central importance for PCK. That is, SMK is a prerequisite for well-structured PCK (Appleton & Kindth, 1999; Henze et al., 2008; Kinach, 2002; Magnusson et al., 1999; Niess & Sholz, 1999; Tobin & McRobbie, 1999; van Driel, Beijaard & Verloop, 2001; Zembal-Saul, Starr & Krajcik, 1999). Thirdly, beliefs of teachers affect their decisions in classroom (Pajares, 1992; Park & Oliver, 2007), and hence their PCK structures. (Gess-Newsome, 1999a; Magnusson et al., 1999; Tobin & McRobbie, 1999; van Driel et al., 2001). Fourthly, PCK develops with classroom practice (Cochran et al., 1993; Crawford, 1999; Gess-Newsome, 1999b; Holt-Reynolds, 2000; Lederman & Gess-Newsome, 1999; Morine-Dershimer & Kent, 1999; van Driel et al., 2001; van Driel, de Jong & Verloop, 2002; Veal, Tippins & Bell, 1999). If teaching experience creates chances for teachers to be active and reflective on their implementations, then it contributes to their PCK development (Abd-El-Khalick, 2006; Park & Oliver, 2007). Finally, PCK can be used as an ‘organizer’ for teacher education, professional development, and certification programs (Berry, Loughran & van Driel, 2008; Carlsen, 1999; Cochran et al., 1993; Gess-Newsome, 1999b; Mason, 1999), because PCK includes what teachers should know and how to organize that knowledge to be able to support students' meaningful and conceptual learning.

2.1.1 PCK Models

Gess-Newsome (1999b) summarized the PCK conceptions of researchers based on their own PCK models. In the simplest form, there are two extreme points about PCK models. On one hand, there is not a unique teacher knowledge named as PCK that is, PCK is a construct comprised by the intersection of other domains. This type of model is named as 'integrative model'. According to the integrative models, teaching is formed by integration of other knowledge domains. On the other hand, some researchers defined PCK as a synthesis of all the other knowledge domains. This type of model is called as 'transformative model' which claims that PCK is a transformation of other knowledge domains into a unique form for effective teaching. According to a transformative model, other knowledge domains are only useful when they are transformed into PCK (Gess-Newsome, 1999b). Figure 2.1 shows the representations of these two types of models.



Integrative Model Transformative Model

* Knowledge needed for classroom teaching.

Figure 2.1 Representations of Models (Gess-Newsome, 1999b, p.12)

Gess-Newsome (1999b) stated that integrative models might create problems during classroom practices. For example, teachers may not realize the importance of integration process and can proceed by emphasizing subject matter knowledge on pedagogy. A possible danger also exists about transformative models. In these models, teachers can make generalizations across different classroom practices; however, this is a difficult process. Because of this difficulty, teachers may ignore the importance of context and have a stable teaching behavior.

PCK model of Grosmann (1990) composed of four central components which are 'conceptions of purposes for teaching subject matter,' 'knowledge of students' understanding,' 'curricular knowledge,' and 'knowledge of instructional strategies'. The first component includes knowledge and beliefs about teaching purposes for a subject at different grade levels. Second one contains knowledge of teachers about student conceptions and misconceptions. What students already know and what learning difficulties and misconceptions they have help teachers to generate useful explanations and representations. Curricular knowledge refers to teacher knowledge about what curriculum materials available for teaching topics in his/her subject area, what students learned in the past, and what they will learn in the future. Last component includes knowledge of representations and instructional strategies for teaching specific topics.

Grossman (1990) offers four different sources contributing to development of PCK which are apprenticeship of observation, disciplinary background, professional coursework, and learning from experience. Apprenticeship of observation provides prospective teachers with memories of instructional strategies and representations for teaching specific topics. This source also support teacher candidates related to knowledge of student understanding. Disciplinary knowledge affects teachers' conceptions of teaching particular topics and selection of curriculum materials. Professional coursework, subject-specific courses for prospective teachers, enriches knowledge of teaching specific topics. Finally, experiences contribute to the development of PCK, because teachers have the opportunity to test and be reflective on their knowledge.

Cochran, DeRuiter and King (1993) modified Shulman's PCK in accordance with constructivist perspective and they preferred to call PCK as pedagogical content knowing (PCKg). PCKg is developing in time via teachers' implementations in classroom context and has four components: 'Knowledge of pedagogy,' 'knowledge of subject matter content,' 'knowledge of students,' and 'knowledge of environmental contexts' (see Figure 2.2). In this model, knowledge of pedagogy also includes curricular knowledge. Cochran et al. (1993) asserted that they placed more emphasis on knowledge of students and environmental contexts than Shulman. Knowledge of students includes 'their abilities and learning strategies, ages and developmental levels, attitudes, motivations, and prior conceptions of the subject they are learning' (Cochran et al., 1993, p. 266). Furthermore, knowledge of environmental contexts refers to teachers' understanding of social, political, cultural and physical environmental contexts which affect the teaching and learning process.

Cochran and her colleagues (1993) emphasized the dynamic nature of PCKg based upon their integrative model. PCKg development depends on the integration of four components stated above. In addition, development of PCKg is a continuing process supported by teaching experience. In this respect, these researchers think that knowledge is a static term and inconvenient with dynamic nature of PCK. Therefore, Cochran et al. (1993) preferred PCKg instead of PCK. Arrows on their model show the continual process of PCK development. In addition to this, the dark place at the center of model represents PCKg which is a different knowledge different from its constituent parts.

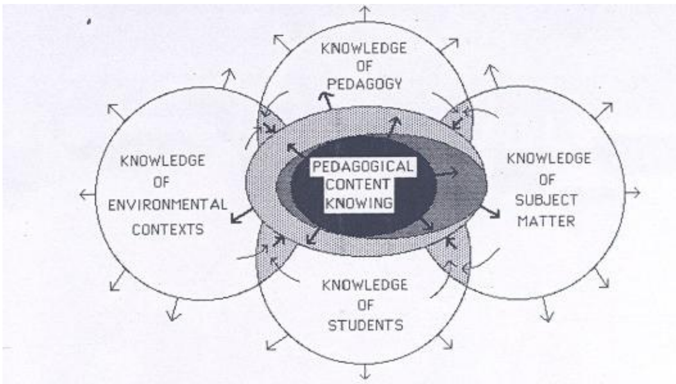


Figure 2.2 PCKg Model of Cochran et al. (1993, p. 268)

Other researchers did not prefer to emphasize the dynamic nature of PCK with its name, but they also had similar conceptions of PCK with Cochran and her colleagues. This model is considering PCK as an integrative process. However, some researchers assert that transformative models seem more appropriate than integrative models for representing science teacher knowledge (Magnusson et al., 1999; Nilsson, 2008). PCK of a science teacher is not an interaction of other types of knowledge placed in teacher knowledge base; it is a transformation of them supported by teaching practice (Nilsson, 2008).

Magnusson et al. (1999) developed a transformative PCK model for science teachers, by building upon the studies of Grossman (1990) and Tamir (1988) (see Figure 2.3). According to this model, PCK emerges from transformation of five components: 'Orientations toward teaching science,' 'knowledge of science curriculum,' 'knowledge of students' understanding of science,' 'knowledge of assessment in science,' and 'knowledge of instructional strategies'.

First component includes beliefs and knowledge of science teachers about goals and objectives of science teaching. This component shapes all the other components, since it serves as a 'conceptual map' for instructional decisions. Second one contains teachers' knowledge about curricular goals and objectives, and applicable materials to achieve these goals and objectives. According to Magnusson et al. (1999), knowledge of science curriculum should be especially included in a PCK model since this type of knowledge distinguishes a content specialist from a pedagogue. Third component includes teachers' knowledge about students' requirements for effective learning and their learning difficulties. Magnusson et al. (1999) grouped student difficulties into three parts. These are abstract structure of concepts and/or lacking of connection between concepts and students' common experiences, lacking of problem solving skills, and disparity between students' prior knowledge and targeted science concepts. Last one is generally called as misconceptions. The researchers emphasized that teachers' knowledge in this component of PCK support them in interpreting students' ideas and actions. Knowledge of assessment in science refers to teachers' knowledge of student learning and scientific literacy that is important to assess and assessment procedures appropriate for different aspects of student learning. Last component of the model includes teachers' knowledge of subject-specific and topic-specific strategies. Scope of subject-specific strategies (such as conceptual change strategies and learning cycle) is wider than topic-specific strategies (such as illustrations and analogies).

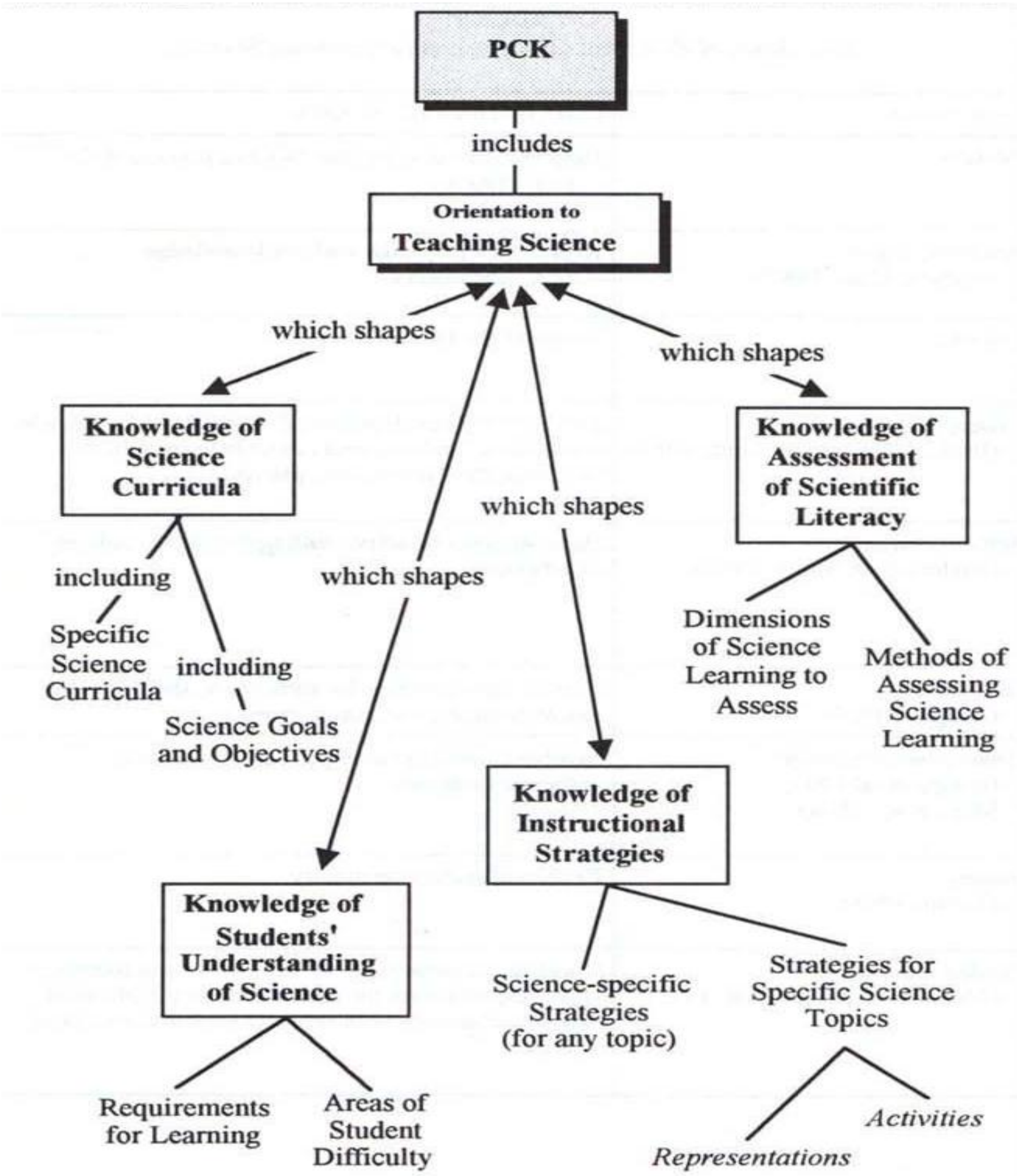


Figure 2.3 PCK Model Developed by Magnusson et al. (1999, p. 99)

Lee and Luft (2008) represented all of the conceptions of PCK models belonging to different researchers in this research area as shown in Figure 2.4. This representation clearly shows that knowledge of student learning and conceptions; and knowledge of representations and instructional strategies are the common components of many PCK models and there is not a hierarchical alignment between these components. This commonality indicates significance of Shulman's first definition of PCK on other researchers, since that definition was only including these two dimensions of the concept. These common knowledge dimensions of PCK were assessed in my study.

	Knowledge of							
Reference	Subject matter	Representations and instructional strategies	Student learning and conceptions	General pedagogy	Curriculum and media	Context	Purpose	Assessment
Shulman (1987)	a	PCK	PCK	a	a	a	a	b
Tamir (1988)	a	PCK	PCK	a	PCK	b	b	PCK
Grossman (1990)	a	PCK	PCK	a	PCK	a	PCK	b
Marks (1990)	PCK	PCK	PCK	b	PCK	b	b	b
Cochran et al. (1993)	PCKg	b	PCKg	PCKg	b	PCKg	b	b
Fernandez-Balboa and Stiehl (1995)	PCK	PCK	PCK	b	b	PCK	PCK	b
Magnusson et al. (1999)	a	PCK	PCK	a	PCK	a	PCK	PCK
Carlsen (1999)	a	PCK	PCK	a	PCK	a	PCK	b
Loughran et al. (2001)	b	PCK	PCK	b	PCK	b	PCK	PCK

Notes: a, distinct category in the knowledge base for teaching; b, not discussed explicitly; PCK, pedagogical content knowledge; PCKg, pedagogical content knowing.

Figure 2.4 Different Conceptualizations of PCK (Lee & Luft, 2008, p. 1346)

2.2 Assessment of PCK

Existing literature shows that studies aiming to develop measures for assessing PCK were mainly concentrated in two educational areas: mathematics education, and science and technology education. Following sections will provide detailed description of some studies in each group.

2.2.1 Assessment of PCK in Mathematics Education

In a project, Study of Instructional Improvement (SII), Hill et al. (2004) studied on 'teachers' knowledge of mathematics for teaching' and achieved to develop measures of this knowledge for large-scale assessment of mathematics teachers. They offered two sets of criteria to develop such measures: proposing a delimited construct and analyzing the data with construct-identification methods (Hill et al., 2008). The researchers selected 'knowledge of content' and 'knowledge of students and content' as the domains of teachers' knowledge of mathematics for teaching. They wrote 138 multiple-choice items focusing on two content areas: number concepts and operations. All of the items were constructed on scenarios because of two reasons. Firstly, scenarios gave a chance to the researchers to represent a context similar to classroom in items. Secondly, teachers were generally avoiding to be measured. Items were divided into three forms by including same content areas and domains equally. Each item was piloted with at least 377 elementary teachers. Exploratory factor analysis showed that two domains mentioned above could be separable. Reliability coefficients for the forms were found as 0.71, 0.73 and 0.78. At the end, they made cognitive interviews to determine convergent validity. In another study, the same researchers found that mathematics knowledge for teaching predicted first and third grade kindergarten students' achievements positively by controlling key student and teacher-level covariates (Hill et al., 2005). This researcher group could directly measure PCK of mathematics teachers instead of using proxy measures such as teaching experience and teacher preparation. However, results of cognitive interviews showed that test-taking skills and mathematical reasoning of participants were effective in selection of correct answers.

Another group of mathematics educators not only tried to measure PCK and content knowledge (CK) of high school mathematics teachers but also showed that PCK and CK are separate domains of teacher knowledge (Krauss et al., 2008). Open-ended survey items written to measure PCK included three subscales: 'Knowledge of mathematical tasks' (4 items), 'knowledge of student misconceptions and difficulties' (7 items) and 'knowledge of mathematics-specific instructional strategies' (10 items). First subscale was intended to measure teachers' awareness of multiple solution paths. Second subscale focused on teachers' knowledge about possible student learning difficulties and misconceptions. Items of this subscale utilized scenarios. Last subscale measured teachers' knowledge about useful representations, analogies, illustrations, etc… accessible to students. There were also 13 open-ended items to measure CK. Survey was implemented on a sample of 198 high school mathematics teachers in Germany. While correct answers were scored 1, items with no response or an incorrect response were coded 0. Sum of the correct answers was calculated. Cronbach alpha reliability of PCK and CK scales were .77 and .83. Confirmatory factor analysis (CFA) showed that PCK and CK are distinguishable knowledge domains. This study produced encouraging results to assess teacher knowledge with open-ended items.

Manizade (2006) also tried to develop survey items for measuring middle school mathematics teachers' PCK about geometry in her dissertation. She mentioned that there was a requirement for describing new ways to assess mathematics teachers' PCK. In this respect, she used Delphi methodology, often used in field of Economics, to construct her survey. This methodology is based on consensus of an expert team around survey items structured by the researcher. Her team included 20 participants in total from researcher experts, mathematics education experts, teacher experts and mathematics education leader experts. The researcher decided to use three multiple rounding of survey items to get suggestions of experts in the team. At the beginning of the study, she identified the dimensions of PCK and constructed 10 open-ended survey items including scenarios. For the first rounding of the items, experts rated items from 1 to 5 and wrote their suggestions. In the second rounding of the survey, experts reviewed the modified items and other experts' comments and ratings for each item. Third rounding was a repetition of second rounding. By conducting qualitative and quantitative data analysis, the researcher constructed the survey including 10 open-ended items. The researcher indeed offered a different methodology to construct such a survey; however, Delphi methodology seems to provide only content related evidence for the validation of items (Fraenkel & Wallen, 1996). Survey was not administered to mathematics teachers, so we could not see whether this survey would yield reliable scores. The survey developed in the study can be a first step for constructing of such measures about PCK within this form.

2.2.2 Assessment of PCK in Science and Technology Education

Halim and Meerah (2002) examined Malaysian science trainee teachers' PCK on selected physics concepts. They administered a survey to 12 trainees for capturing their knowledge about representing physics concepts to lower high school students. Another data came from interviews conducted for the purpose of investigating trainee teachers' knowledge about student conceptions and knowledge about representation ways of physics. As a result of their study, researchers stated that trainees' deficiency in content knowledge prevented them to have a well-structured PCK. Selecting a qualitative design forced them to include low number of participants in the study. Studying with trainee teachers in a PCK assessment study is also problematic since the existing literature emphasizes the necessity of (teaching) experience on development of PCK.

An Australian group of science educators invented a way to capture and portray PCK of science teachers (Loughran et al., 2001; Loughran, Mulhall & Berry, 2008; Loughran et al., 2004; Mulhall, Berry & Loughran, 2003). Over a two-year study period, with a sample of 50 high school science teachers, they developed two tools: Content Representation (CoRe) and Professional experience Repertoires (PaP-eRs). CoRe was developed to measure what the critical aspects of a specific science topic are and what students know about this topic. This tool can be used not only for assessing science teachers' understanding of the content but also for a research tool (Loughran et al., 2004). The researchers implemented CoRes as interview tools with small groups including three or four high school science teachers. Attached to CoRe, PaP-eRs provide researchers opportunity to get details about teaching process in practice of each teacher. Data for PaP-eRs comes from individual interviews and classroom observations. One of the most important aspects of these research tools is that a CoRe should be attached to more than one PaP-eR since PaP-eRs are focusing on specific implementations of science teachers in the classroom.

This study contributed to the existing literature by showing a way not only for capturing science teachers' PCK on a science topic but also showing tacit nature of this knowledge to others. Validation was provided through a drafting process between researchers and teachers. Assessment seems as a second purpose for the researchers, but it is blurred how it can be possible based on the tools developed in their studies. In addition, it is not possible to study with a large sample of science teachers since it will not be feasible in terms of amount of time. Finally, CoRes and PaP-eRs force teachers to invest much effort and time while capturing and representing their PCK.

Another group of researchers from Holland tried to measure primary technology teachers' PCK focusing on three aspects: 'Knowledge of student conceptions,' 'knowledge of teaching strategies,' and 'knowledge of nature and purpose of technology education' (Rohaan et al., 2009). They benefited from Kromrey and Renfrow's (1987) ideas to create multiple-choice items. Kromrey and Renfrow (1991) introduced researchers with 'content-specific pedagogical knowledge' (C-P) items that represent teachers' determination of treatment preference for specific teaching contexts. By considering C-P items, Rohaan et al. (2009) constructed 40 multiple-choice items which present teachers scenarios. These scenarios included problematic situations for classroom contexts in terms of students' understanding of technology and asked teachers about what they would do next. 40 multiple-choice items were divided into two equal forms and piloted on a sample of 120 teachers. They selected 19 items by analyzing reliability of pilot study data and retested the final form on 101 teachers. At the end, they constructed a 19-item multiple-choice test with a test-retest reliability coefficient of 0.36.

This study tried to measure PCK in a transformative way. That is, the researchers measured all three aspects of PCK in each item. Reliability score of the test provided us to consider assessing physics teachers' PCK component by component even if PCK has a transformative structure. Another criticism to this study can be made about the criteria about right answers of multiple-choice items. Although, there is not a standard for appropriateness of teaching strategies related to any classroom context in existing literature; the authors approximated as if there is.

German researchers developed a paper and pencil instrument including 13 open-ended and 3 multiple-choice items for measuring primary science teachers' PCK (Lange, Kleickman & Möller, 2009). The researchers benefited from Magnusson et al.'s (1999) PCK model and focused on dimensions of knowledge of student understanding and knowledge of instructional strategies. The test was piloted on 115 science teachers and final implementation was made on 107 teachers. They found a reliability score of 0.71 at the end. This study seems yielded encouraging results for the purposes of this study.

Uşak (2005) studied on prospective elementary science teachers' PCK about flowering plants in his dissertation. This study included 4 prospective elementary science teachers and used case study as the methodology. The researcher collected data by video records of observed lessons, concept maps, lesson plans, word association tasks, written documents and interviews. Data triangulation showed that relation between prospective teachers' SMK and PCK is not constant among participants. In addition to this, prospective teachers have misconceptions about the topic they teach. Another important finding of this study is that development of PCK is a gradual process. In abstract, Uşak's (2005) dissertation produced descriptive results related to structure of prospective teachers' PCK. Because of the case study design, number of participants is not enough to make generalizations about PCK structures of prospective elementary science teachers.

Canbazoğlu (2008) assessed prospective elementary science teachers' PCK related to structure of matter by utilizing case study methodology in her dissertation. The sample included 5 prospective teachers. Data was collected by classroom observations, interviews and written documents. This study shows that SMK is a prerequisite for PCK, but not enough without other knowledge domains such as knowledge of curriculum, knowledge of student understanding, knowledge of instructional strategies. Prospective teachers, having teaching experience in their subject area, possess more qualified and effective PCK than other prospective teachers who have not any teaching experience. Results of this study are consistent with existing literature.

2.3 Self-Efficacy

Self-efficacy refers to perceived beliefs, judgments, or capabilities of a person for performing actions at designated levels (Bandura, 1977). Pajares (2002) stated that self-efficacy beliefs serve people as a mechanism instrumental to achieving and exercising their goals over their environment. According to Bandura (1982) self-efficacy judgments of people have four main information sources which are enactive attainments, vicarious experience, verbal persuasion and physiological state.

Enactive attainments have the most influential effect on self-efficacy information since they can be based on mastery experiences that is people’s own successes and failures. Vicarious experiences is taking someone, performing similar performances, as a model and comparing one’s own capabilities with the model. Verbal persuasion is discourses coming from others to make the people to believe that they have the needed capabilities for achieving what they want to perform. Finally, physiological state includes people’s judgments regarding their capabilities in terms of their own physical and emotional situations (Bandura, 1982).

Bandura (1982) stated that people could not isolate themselves from society. Additionally, many of the challenges, which people encounter, are parts of their societies. In this respect these challenges require collective efficacy which influences people’s choices as a social group. As a different concept from PSE, perceived collective-efficacy ‘reflects the beliefs members of an organization hold about their capacity to operate in concert and to create the needed synergies among different roles and expertise to meet adequately the obligations and challenges of the group or organization’ (Caprara et al., 2003, p.821).

There are two dimensions of self-efficacy: personal self-efficacy and outcome expectancy. Personal self-efficacy is “belief in one’s capabilities to organize and execute the courses of action required to produce given attainments, whereas outcome expectancy is a judgment of the likely consequence such performances will produce” (Bandura, 1997, p.3, as cited in Cantrell, Young & Moore, 2003).

2.3.1 Teacher Self-Efficacy

Research studies in this area dates back to introduction of self-efficacy by Bandura. Teacher self-efficacy refers to the beliefs of teachers in their capabilities and abilities affecting students’ learning (Gibson & Dembo, 1984; Swackhamer et al., 2009). Researchers have found two separate dimensions of teacher self-efficacy by the impact of Bandura’s social cognitive theory: personal teaching efficacy and outcome expectancy (Tschannen-Moran, Woolfolk Hoy & Hoy, 1998).

Teachers with high levels of PSE believe that they can positively affect student achievement (Viel-Ruma et al., 2010). High-efficacy teachers have higher persistence in their students’ learning failure and higher expectations on their students in comparison with low-efficacy teachers. This situation has a direct and positive effect on their students’ meaningful learning and achievements (Gibson & Dembo, 1984; Tschannen-Moran et al., 1998).

Tschannen-Moran and her colleagues developed the model cyclical nature of teacher efficacy (see Figure 2.5) to present the conceptual issues regarding teacher self-efficacy and to suggest new research areas. The model starts with the four different information sources of self-efficacy stated by Bandura. In the cognitive processing period, teachers determine impacts of the four different information on analysis of teaching task and assessment of personal teaching competence. In the next step, teachers analyze teaching tasks in terms of requirements such as student abilities and instructional strategies, and make assessment of personal teaching competences whether their current abilities are convenient for the intended teaching task. Tschannen-Moran et al. (1998) define teacher self-efficacy as ‘the teacher's belief in his or her capability to organize and execute courses of action required to successfully accomplish a specific teaching task in a particular context’ (p.233). The researchers stressed the context specific structure of teacher self-efficacy. Following the performance in classroom a new information source is added to the model. They said that cyclical structure of teacher efficacy represents one of the most powerful aspects of it, because of this way, teachers can have greater efficacy beliefs so greater performances in their futures.

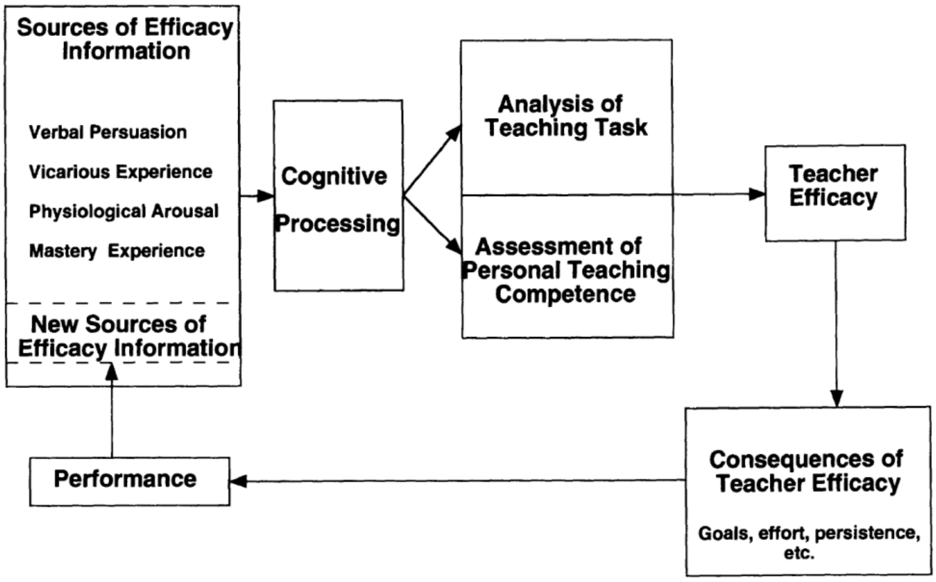


Figure 2.5 The cyclical nature of teacher efficacy (Tschannen-Moran et al., 1998)

2.3.2 Assessment of Teacher Self-Efficacy

Gibson and Dembo (1984) developed a Likert-scale instrument including 30 items for assessment of teachers’ self-efficacy by considering Bandura’s theory. They found two different factors as a result of factor analysis consistent with the theory and labeled the factors as personal teaching efficacy and general teaching efficacy (outcome expectancy). In following studies some researchers found that several items of this instrument were loaded on both factors, therefore another version of the instrument including 16 items was used by some other researchers (Tschannen-Moran et al., 1998).

Gibson and Dembo (1984) asserted that teachers getting higher scores on both dimension of the instrument would persist longer, provide different types of feedback to their students and be active in their lessons than other teachers. Many researchers supported the findings of this study.

Considering the context and subject-matter specific nature of teacher self-efficacy some researchers tried to adapt the existing efficacy instruments to this specificity (Tschannen-Moran et al., 1998). Riggs and Enochs (1990) developed a Likert-scale instrument consisting of 25 items to assess efficacy of teaching science based on Gibson and Dembo's study. They also found two different factors labeled as personal science teaching efficacy and science teaching outcome expectancy.

In a following study, Rubeck and Enochs (1991, as cited in Tschannen-Moran et al., 1998) goes further in subject-matter specification of the instrument. In that study researchers tried to measure not only science teaching self-efficacy but also chemistry teaching self-efficacy of high school teachers. The researchers could distinguish science teaching self-efficacy from chemistry teaching efficacy and found that the first one was significantly higher than the second one.

Among the discussions related to context or subject-matter specificity assessment of teaching efficacy, Bandura (1997, as cited in Tschannen-Moran et al., 1998) offered a new instrument including 30 Likert-items. Bandura stated that teaching efficacy was 'not necessarily uniform across the many different types of tasks teachers are asked to perform, nor across different subject matter' (Tschannen-Moran et al., 1998, p.219). Bandura's instrument is including seven sub-scales: efficacy to influence decision making, efficacy to influence school resources, instructional efficacy, disciplinary efficacy, efficacy to enlist parental involvement, efficacy to enlist community involvement, and efficacy to create a positive school climate.

Caprara et al. (2003) also developed an instrument for assessment of PSE of junior high school teachers. The instrument included 12 Likert-items independent from context and subject-matter. Actually, Caprara and his colleagues tried modeling the relations among teachers' PSE, perceived collective-efficacy and JS within school organizations. As a result of the study, they declared that PSE was predicting JS directly and positively.

2.4 Job Satisfaction

JS refers to the degree of satisfaction an employee discloses regarding his/her work (Fuming & Jiliang, 2008) and attitudes that an employee has related to his/her job (Mahmood et al., 2011). In this respect, JS is a multidimensional psychological response, including cognitive, affective and behavioral components; to an employee's his/her own job (Hulin and Judge, 2003).

Van der Heijden and Brinkman (2001) state that JS is an emotional (affective) state rather than a personal characteristics. They emphasize that people satisfy with their job if they achieve job requirements. This achievement can be provided when people develop their professional knowledge. The researchers provided evidence in study (consisting of 559 employees working in Dutch companies) that people's JS level predicted their professional knowledge (Van der Heijden & Brinkman, 2001).

Many attempts have been realized for assessment of JS. Researchers developed different assessment tools among which the Job Descriptive Index, the Job Diagnostic Survey, the Minnesota Satisfaction Questionnaire and the Index of Organizational Reactions are the mostly preferred ones in research studies. The most widely applied assessment tool for JS is the Job Descriptive Index including 72 items in total focused on five facets of JS: work itself, pay, promotional opportunities and policies, supervision, and coworkers (Hulin and Judge, 2003; Stanton et al., 2001).

2.4.1 Teachers' Job Satisfaction

Recent studies show that JS has a meaningful effect on peoples' job performances (Hulin and Judge, 2003). Therefore, it can be asserted that teachers' JS affects their classroom performances and their students' achievements (Caprara et al., 2003; Klassen, Usher & Bong, 2010; Viel-Ruma et al., 2010).

Studies on teachers' JS provide deeper understanding of teachers' attitudes towards school and contribute to the development of quality of teaching and education (Fuming & Jiliang, 2008). Fuming and Jiliang (2008) offered an increase in welfare benefits of teachers and quantity of software and hardware materials of high schools , and a decrease in principal factors and class sizes for raising teachers' JS.

Klassen, Usher and Bong (2010) examined the relationship between teachers' collective efficacy and JS. They used JS instrument, adapted from the Job Descriptive Index by Caprara et al. (2003), in the study. The study included 500 elementary and high school teachers from Canada, Korea (South Korea or Republic of Korea), and the United States. As a result of the study they found that there was a significant relationship between teachers' JS and collective efficacy.

2.5 The Relation among Teachers' Pedagogical Content Knowledge, Perceived Self-Efficacy and Job Satisfaction

PCK was firstly introduced by Shulman as a part of teachers' practical knowledge developing with classroom implementation and experience (Wilson et al., 1987). What Shulman referred with experience is the transformation of knowledgebase dimensions of a teacher (Wilson et al., 1987) followed by reflections in/on classroom implementations (Abd-El-Khalick, 2006; Park & Oliver, 2007). These reflections have vital effects on teachers' pedagogical reasoning regarding their future implementations. The magic under this pedagogical reasoning process is that it seems impossible to be completed, since

PCK has a context-based structure. Therefore, a teacher's future implementations will create new reflections and encircling will continue (Wilson et al., 1987).

Within the action oriented and context-bound structure (Gess-Newsome, 1999b), teachers' practical knowledge, be seen as the core of teachers' professionality, is a combination of teachers' experiential knowledge and personal beliefs (van Driel et al., 2001). The model, representing cyclical nature of teacher efficacy offered by Tschannen-Moran et al. (1998), has almost the same circling with transformation process of Shulman. Additionally, the model highlights the term 'experience' distinctively since mastery experiences of teachers have the most influential effect on their self-efficacy (Bandura, 1982). Beside of this, literature offers some other commonalities between teachers' PCK and self-efficacy.

Yoon et al. (2006) investigated the relationship between teachers' PCK and self-efficacy. 12 elementary pre-service science teachers were participated in the study. Teachers' PCK was developed with the case method which spanned a total of 3 hour. Based on the data triangulation, they found that case method provided pre-service science teachers to gain confidence in their understanding of PCK which, in turn, positively affected their self-efficacy beliefs. Some other researchers also found the same relationship between PCK and self-efficacy of pre-service science teachers (Mulholland & Wallace, 2001; Palmer, 2001).

Lin and Tsai (1999) examined the relationship between teaching efficacy and PCK among in-service and pre-service science and math teachers. There were 11 expert teachers (having an average 11 years of teaching experience), 8 beginner teachers (in their first year of teaching) and 12 pre-service teachers. Based on the video records, interviews and teaching efficacy scale data they found that expert and beginner teachers had more qualified in their PCK and teaching efficacy.

Swackhamer et al. (2009) investigated the relationship between PCK and self-efficacy of middle school science and mathematics teachers in a 5-year project study. 88 in-service teachers participated in the study. The main goal of the project was to develop SMK and PCK of middle school teachers. Based on the survey and interview results, they asserted that when PCK of middle school teachers was developed, their outcome expectancy was also impacted positively. In a similar study, Posnanski (2002) inspected the effects of a 32-week professional development program on in-service science teachers. Qualitative and quantitative data analyses showed that in-service teachers' PCK levels and personal science teaching efficacy beliefs were enhanced significantly.

In another study, Khourey-Bowers and Simonis (2004) examined the effects of a 4-year professional development program on 135 middle school chemistry teachers on their science teaching efficacy and PCK levels. They found significant increases both in teachers' personal science teaching efficacy and outcome expectancy with positive changes in PCK levels. They stressed that inclusion of both in-class and out-of-class assignments and actual teaching tasks to their program as the main factor of positive changes in teachers' PCK and self-efficacy levels.

In addition to parallel research findings regarding teachers' self-efficacy and PCK levels, based on the results of a multiple case study, Park and Oliver (2008) offered a new model (see Figure 2.6) to re-conceptualize the structure and components of PCK for science teaching. The model includes some common components of PCK similar to other models with a remarkable new one: teacher efficacy. They described this component as that "highly subject specific version of teacher efficacy in that it was related to teacher beliefs about their ability to enact effective teaching methods for specific teaching goals and was specific to classroom situations/activities" (Park & Oliver, 2008, p.270).

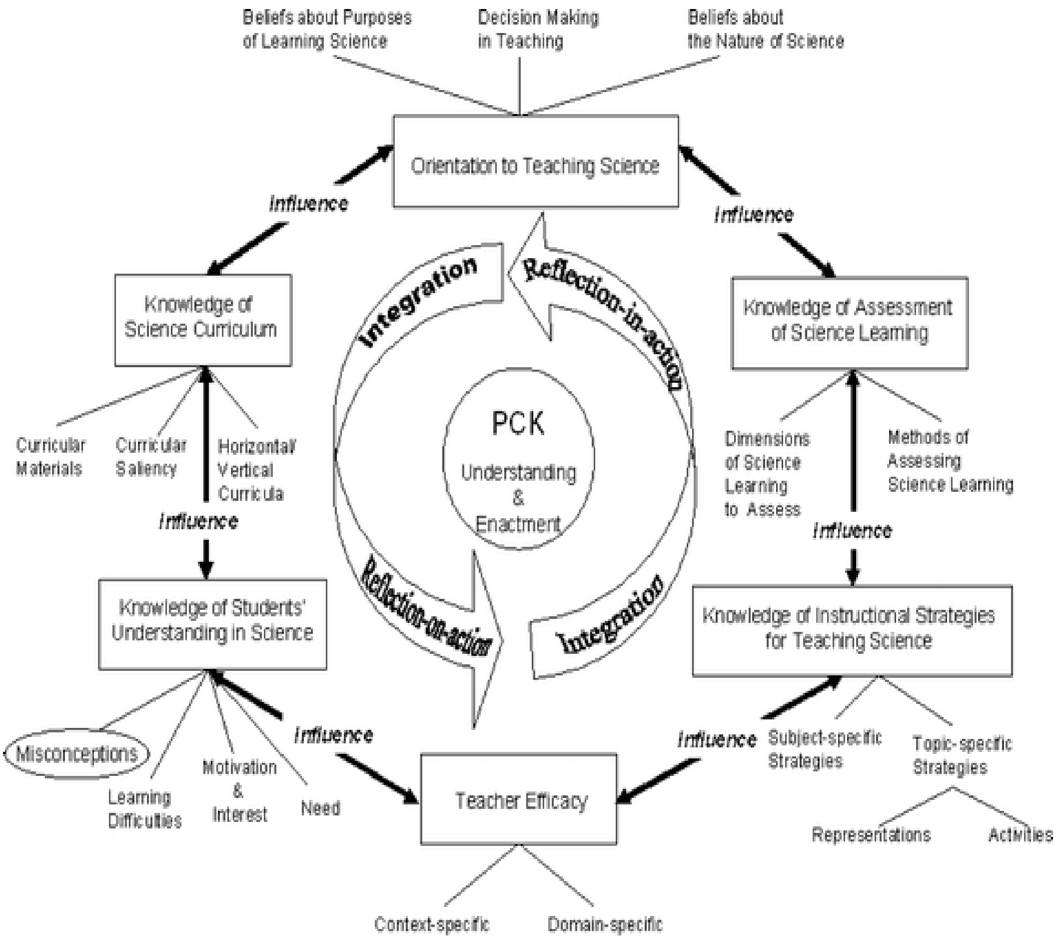


Figure 2.6 PCK Model of Park & Oliver (2008)

As a result, some research studies stated above, provides evidence that there is a relationship between teachers' PSE and PCK. Some other researchers also state that teachers' beliefs have a potential to affect their PCK structures (Gess-Newsome, 1999a; Magnusson et al., 1999; Tobin & McRobbie, 1999; van Driel et al., 2001).

Regarding these findings, we can state that teachers' PCK and teaching efficacy beliefs can affect their classroom implementations and decisions as parts of their practical knowledge. JS is also another construct possessing an effective potential on teachers' classroom practices. In some studies researchers found that teachers' PSE beliefs is predicting their JS level positively and directly (Caprara et al., 2003; Viel-Ruma et al., 2010).

Azar and Henden (2003) identified JS level of primary school teachers in a survey study. 2450 primary school teachers, be assigned out of their profession, participated in the study. They found that participated teachers had low scores in JS. Based on the results they offered implementation of a non-thesis pedagogical education program or a professional development program for improving these teachers' practical knowledge. Fuming and Jiliang (2008) also stated that professional development programs aiming to support teachers' qualifications might provide teachers to realize their values in teaching, then, this realization could arise in teachers' JS.

2.6 The Summary of the Literature Review

I divided the reviewed studies related to PCK in several sections systematically. First section of the literature review focused on conceptions of different researchers regarding PCK and their PCK models. Second section represented the assessment studies related to PCK in mathematics, and science and technology education. Following sections provided information regarding teachers' PSE beliefs and JS.

PCK is a topic-specific construct including teachers' knowledge of representations, student difficulties and misconceptions. It is acting in teachers' practices and helps teachers to transport their knowledge to learners. SMK has a central importance but not enough alone for a comprehensive PCK. In this regard, modeling studies show that PCK is an integration or transformation of other knowledge domains. For an integrative model, PCK is not a knowledge domain by itself; it is the integration of other knowledge domains. Possible problem with this model is that teachers may never see the importance of integration and neglect the importance of pedagogy. For a transformative model, PCK is a unique knowledge domain constituted by other knowledge domains via transformation. However, teachers may neglect the educational contexts and possess a stable teaching manner within this model.

I also explained some PCK models with details in this part. Knowledge of student learning and conceptions, and representations and instructional strategies are the common knowledge domains of many PCK models. Researchers' conceptions related to these common knowledge domains are also very similar.

In the second part of the literature review, I presented studies related to assessment of PCK in mathematics, and science and technology education. In mathematics education, assessment instruments include only multiple-choice items or open-ended items. There are not any instruments including both of these types of items. By conducting exploratory or confirmatory factor analysis, researchers found that PCK and CK are separate domains of teacher knowledge base. However, test-taking skills of teachers were found effective in their correct responses for multiple-choice items.

Studies regarding PCK assessment in science and technology education generally utilized qualitative designs, especially case studies. These studies seem to produce descriptive results which may be used to categorize teachers in terms of their PCK. Rohaan et al. (2009) wrote only multiple-choice items to assess technology teachers' PCK in three dimensions of PCK: 'Knowledge of student conceptions,' 'knowledge of teaching strategies,' and 'knowledge of nature and purpose of technology education'. This study yielded low reliability for test scores. This may because of measuring all the three dimensions of PCK together in each item. Furthermore, Lange et al. (2009) could develop an instrument, including open-ended and multiple-choice items, for assessing primary science teachers' PCK. They focused knowledge of student understanding and knowledge of instructional strategies from Magnusson et al's (1999) model of PCK. The study yielded reliable scores.

In the remaining parts, I presented some studies asserting that teachers' PSE beliefs and JS level affect their persistence in teaching even if the learning environment has some negative sides. Some researchers found a remarkable relation between teachers' PCK and their self-efficacy beliefs. The similarities between structures of PSE and PCK support the researchers stating that PSE has a potential in predicting PCK.

2.6.1 Decisions Taken by Analyzing the Literature

By analyzing the literature stated above we decided to:

1) Focus on two components of PCK and utilize the following Table of Specifications as a basis of our assessment tool. Why we focused on these two components is that the common trends in PCK modeling studies. These two components had equal weights on total (assessment) scores of teachers because we could not detect a hierarchical alignment between these components.
2)

Table 2.1 Table of Specifications

Components of PCK	Objective
Knowledge of Students' Understanding of Electricity (KSUE)	Write pre-instructional thinking, experiences and views of students causing learning difficulties and misconceptions related to electricity.
	Give examples of student misconceptions in electricity and refute them.
Knowledge of Instructional Strategies (KIS)	Adapt useful representations or instructions for overcoming students' learning difficulties and misconceptions related to electricity.

3) Benefit from advantages of both qualitative and quantitative designs in assessment of teachers' PCK. Assessment in the first component was realized quantitatively, but we conducted both qualitative and quantitative analyzes for the KIS component.
4) Write open-ended items instead of multiple-choice items since for the latter, teachers' test-taking skills may affect their right answer selection.
5) Construct a paper and pencil assessment instrument whose results can be clearly interpreted and which assess physics teachers' PCK in accordance with what they possess about focused components of PCK in electricity.

6) Utilize multiplicity in teachers' representations in accordance to the students' learning needs/situation as a positive indicator for KIS.
7) Utilize teachers' years of teaching experience, specific experiences regarding students' learning difficulties and misconceptions, PSE level, JS level and attendance to in-service training seminars regarding physics teaching programs as predictors for teachers' PCK in validation processes.

CHAPTER 3

METHODOLOGY

The methodology chapter explains the research design, description of the population and sample, variables of the study, description of instruments used for data collection, procedure by which the study was conducted, rubric preparation, description of the statistical techniques used in analyzing the results, limitations and assumptions of the study.

3.1 Research Design

The purpose of this study was to assess PCK of physics teachers about electricity topic in high school level by developing a paper and pencil instrument consisting only open-ended items. In this regard, the instrument was distributed to the participants, and therefore; the methodology of the study is cross-sectional survey since I would collect the data 'at just one point in time' (Fraenkel & Wallen, 1996, p.368; Johnson, 2001).

3.2 Population and Sample

Target population of the study is all the in-service high school physics teachers in Turkey. Sample (regarding all the implementations during test construction period) included 278 in-service physics teachers. In final implementation, PECKI was administered to 124 high school physics teachers, by convenience sampling from different parts of Turkey. 76 male (61.3%) and 48 (38.7%) female teachers participated in the final implementation. 56 of the participants were the teachers who participated in an in-service training seminar in

June 2011. Remaining 68 participants were found by convenience sampling from different cities of the country. We tried to include participants from different cities of the country as many as possible for closing to the distribution of cities in the target population of the study. Accessible population of the study was limited with the cities of participants shown in Table 3.1. There are 2997 physics teachers in the accessible population; therefore, while our whole implementations included 9 % of the population, final implementation included 4.1% of the population.

Table 3.1 Distribution of Sampling

	Number of Participants			
Place	First Implementation	Second Implementation	Third Implementation	Final Implementation
Adıyaman	-	-	-	1
Ankara	6	6	52	29
Ardahan	-	-	-	1
Bursa	4	4	-	21
Çanakkale	-	-	-	2
Erzincan	-	-	-	1
Eskişehir	-	-	-	4
Giresun	-	-	-	1
Iğdır	-	-	-	1
İzmir	-	-	-	5
K.Maraş	4	4	-	6
Kastamonu	-	-	-	2
Kayseri	-	-	-	3
Kırşehir	16	16	16	12
Kocaeli	-	-	-	11
Mersin	-	-	-	4
Nevşehir	-	-	26	12
Samsun	-	-	-	2
Ş.Urfa	-	-	-	1
Tokat	-	-	-	1
Tunceli	-	-	-	2
Yozgat	-	-	-	2

For the sake of confidentiality, participants were not required to write down their names and schools. Teaching experience, participants' cities, the number of in-service trainings related to physics teaching programs attended by teachers, teachers' departments of graduation, gender of participants, and the type of high schools that they are working were asked, so confidentiality was not be a threat for my study. Table 3.2 represents the distribution of teachers (participated in final implementation) in accordance to the type of schools that they are working.

Table 3.2 Distribution of Participants' Schools

School Type	Number of Participants*
High School	37
Vocational High School	30
Anatolian High School	44
Science High School	5

*8 participants did not stated the school type they are working

3.3 Instruments

Three different instruments to collect data regarding participant teachers' PCK, PSE and JS were used in the study. PECKI was developed by the researcher, and the other two were adapted from the study of Caprara et al. (2003). Following is a detailed account of the development of PECKI and the adaptation of PSEI and JSI.

3.3.1 Pedagogical Electricity Content Knowledge Instrument (PECKI)

In this study, we developed Pedagogical Electricity Content Knowledge Instrument (PECKI). PECKI included 15 open-ended items before the final implementation. Distribution of items in accordance to the objectives, table of test specifications, can be seen in Table 3.3. Each item in the same dimension had equal effects on total score of physics teachers.

Items of the first two objectives were evaluated only quantitatively by means of the rubric developed in the study. Items constructed for the last objective were evaluated both qualitatively and quantitatively. The main reason for this type of evaluation is to produce a distribution representing which instructional strategies are preferred by in-service high school physics teachers in Turkey. Each participant had a total score at the end of the scoring procedure. I explained the details about scoring of the instrument in next section of this chapter.

Table 3.3 Table of Test Specifications for PECKI

Components of PCK	Objective	Item Number
Knowledge of Students' Understanding of Electricity (KSUE)	Write pre-instructional thinking, experiences and views of students causing learning difficulties and misconceptions related to electricity.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
	Give examples of student misconceptions in electricity and refute them.	15
Knowledge of Instructional Strategies (KIS)	Adapt useful representations or instructions for overcoming students' learning difficulties and misconceptions related to electricity.	11, 12, 13, 14

By analyzing the literature, we decided (in PECKI) to include two dimensions. In the first implementation, we developed an instrument which included 3 open-ended questions (see Appendix A) and asked 30 in-service physics teachers from high schools in different cities to write their students' common misconceptions and learning difficulties related to electricity together with the instructional strategies they use for overcoming them.

Following this implementation, the instrument for the second implementation was constructed which included 19 open-ended items (see Appendix B). We paid special attention to include most frequently repeated student learning difficulties and misconceptions stated by the participant teachers of the first implementation. In addition to these most frequent student misconceptions and learning difficulties, three items (Items 9, 10 and 11) from a dissertation study (Peşman, 2006) regarding student misconceptions in electricity were adapted to be included in the second version of the instrument. This instrument was given to co-supervisor and one physics educator for face and content validation and then distributed to the same teachers from the first implementation to control understandability. At the same time, teachers were also asked to answer the questions in the test. Another aim of this implementation was to transform the items into restricted response open-ended questions which would require at most three or four sentences to answer.

Based on the results of the second implementation, we made some corrections on some of the figures and statements represented in items to arise understandability. In items 12, 15 and 18 participants gave the same answers. We decided to delete these three items from the instrument since they could not make a differentiation among the participants' responses.

Third version of the instrument (see Appendix C) were divided into two equal parts and distributed to 116 high school physics teachers from different cities of the country. 94 teachers responded to this version of the instrument. In this implementation, we asked teachers to time how long they spent answering the questions in order to predict the whole instrument's answering. This implementation also served us to prepare the evaluation rubric for the final implementation.

Based on the results of the third implementation Item 9 and first sub-questions of items 11 and 15 (in third version of PECKI) were extracted from the instrument, because we could not observe a variation in teachers' responses for these questions. At the beginning of this implementation, items 11 and 15 had two different sub-questions constructed for two different objectives of the instrument.

By deleting first sub-questions, items 11 and 15 were completely directed to last objective of PECKI. In addition to these changes, we decided to change item 16, since teachers were required to write only refutation sentences for the misconceptions represented in that item and this was mostly measuring teachers' SMK rather than their PCK. And also, we constructed an additional part under all PECKI items except for the last one to observe contribution of teachers' specific experiences to their PCK.

Just before the final implementation, the instrument which included 15 open-ended items (see Appendix D), was presented to two physics educators and two PhD candidates from the physics education department of METU for face and content validation purposes.

The researcher or trainer distributed the final version of the instrument to the participants by providing a short introduction regarding the study. PECKI forms also introduced the participants regarding the aims of the study itself. Time limitation was not performed during implementations. Forms were collected in following three days of distribution. Participants answered questions in the final version of PECKI at their spare times. Items require teachers to think about their classroom implementations and students' learning difficulties or misconceptions efficiently and then write their responses. In this regard, we thought our approach about implementers, place, and time limitation increased participant teachers' response rates to the items.

3.3.2 Perceived Self-Efficacy Instrument (PSEI)

Perceived self-efficacy instrument (PSEI) included twelve likert type items measuring teachers' PSE. PSEI was distributed to the teachers during final implementation and presented on the second page of PECKI. The instrument was adapted (by back translation of 2 foreign language educators) from the research study of Caprara et al. (2003) (see Appendix E). The researchers provided construct-related evidence with CFA. They found the cronbach alpha reliability as

0.74. We presented reliability score regarding our implementation in the next chapter.

3.3.3 Job Satisfaction Instrument (JSI)

We measured teachers' JS with four likert type items. This instrument was distributed to the teachers during final implementation and presented on the second page of PECKI. Job satisfaction instrument (JSI) was adapted (by back translation of 2 foreign language educators) from the research study of Caprara et al. (2003) (see Appendix E). The researchers provided construct-related evidence with CFA. They found the cronbach alpha reliability as 0.82. The study was introduced to 2688 high school teachers. Klassen et al. (2010) administered the same test to a total of 500 elementary and high school teachers from Canada, Korea (South Korea or Republic of Korea), and the United States and found the reliability of the JSI as 0.83 (for Canadian teachers), 0.87 (for Korean teachers), and 0.83 (for USA teachers) respectively. We presented reliability score regarding our implementation in next chapter.

3.4 Variables

Variables of this study were obtained with final implementation of PECKI. Following sub-sections contains detailed information regarding variables of the study. Data regarding all the variables were collected in final implementation. Teachers were asked to write down their years of teaching experience and the number of attendance to in-service training seminars related to physics teaching program on the first page of PECKI (see Appendix D).

3.4.1 Pedagogical Content Knowledge

It is a continuous variable obtained from the final implementation of the instrument. PCK score corresponds to participants' level of pedagogical content knowledge related to teaching of electricity. There were fifteen open-ended items measuring this variable. PECKI had two different dimensions named as knowledge of students' understanding of electricity (KSUE) and knowledge of instructional strategies (KIS). PECKI score was found by summing the participants' scores in these two dimensions. Total maximum score available for this test is 52 whereas the minimum score available is 0.

3.4.2 Perceived Self-Efficacy

It is a continuous variable obtained from the final implementation of the instrument. PSE score corresponds to participants' PSE level. There were twelve 5-point Likert items measuring this variable. Total maximum score available for this test is 60 whereas the minimum score available is 12.

3.4.3 Job Satisfaction

It is a continuous variable obtained from the final implementation of the instrument. JS score corresponds to participants' JS level. There were four 5-point Likert items measuring this variable. Total maximum score available for this test is 20 whereas the minimum score available is 4.

3.4.4 Year of Teaching Experience

It is a continuous variable obtained from the final implementation of the instrument. Year of teaching experience corresponds to years of participants' teaching experience. We asked participants' years of teaching experience on the first page of PECKI.

3.4.5 Specific Experience

It is a continuous variable obtained from the final implementation of the instrument. Specific experience score corresponds to whether participants having previously experienced a specific student learning difficulty or misconception. Under all PECKI items except for the last one, we asked participants to select if the sources of their knowledge were their experience or their reasoning; or write down the name of sources if they select ‘other’. There were only 7 ‘other’ responses given out of possible 1736. Therefore, we neglected the ‘other’ category and coded them as reasoning in dataset, because these teachers stated they did not previously experience the student learning difficulty or misconception represented in that item. Furthermore, there were 12 responses in which nothing was selected as alternative or written an information source in other category. We coded these cases manually as experience or reasoning by skimming the previous answers of those teachers to similar items. Experienced teachers got 1 point score for that item; hence each participant had a score out of 14 in this variable. The minimum score available for this variable of the study was 0.

3.4.6 In-service Training Attendance

It is an ordinal variable obtained from the final implementation of the instrument. We asked participants how many times they attended an in-service training seminar regarding physics teaching programs.

3.5 Procedure

At the beginning of the study, I reviewed the international and national secondary sources in detail, by focusing on PCK and teacher knowledge. Then, keywords were identified as ‘physics teacher;’ ‘science teacher;’ ‘teacher knowledge base;’ ‘pedagogical content knowledge;’ ‘measurement of teacher knowledge;' 'teacher assessment;' 'teacher self-efficacy;' and 'teachers' JS.' Next, these keywords were searched on Educational Resources Information Center (ERIC), Ebscohost, Science Direct, Social Science Citation Index, International Dissertation Abstracts, Google and Google Scholar. Hacettepe Üniversitesi Eğitim Fakültesi Dergisi and Milli Eğitim Dergisi were also searched for the above keywords. Finally, online service of the Council of Higher Education (YÖK) were searched in detail for theses containing the above keywords.

Based on the literature review and follow up implementations of the initial versions of the PCK instrument, PECKI was developed and submitted to the Middle East Technical University of Human Researches Ethic Committee for the approval of the study (see Appendix F). In addition to this approval, permission of the Turkish Ministry of National Education was taken for administration of the survey to physics teachers during the in-service training seminar held in June, 2011, Aksaray (see Appendix G). Obtaining the approval and the permission took approximately 6 weeks.

Finally, PECKI was distributed to 65 physics teachers attending the in-service training. 56 PECKI forms were returned. We also distributed PECKI to other 86 teachers, and received 68 PECKI forms. Consequently, final implementation of PECKI included 124 high school physics teachers. Procedure for data analysis was explained in the following sections.

3.6 Scoring Method

Miller et al. (2008) suggested two types of scoring methods for open-ended items: 'analytic scoring' and 'holistic scoring'. In analytic scoring rubrics, evaluators should focus on one aspect of the answer at a time. The most important characteristic of this type of scoring method is to provide participants with detailed feedback via separate scores attained to their responses in terms of different aspects. On the other hand, holistic scoring offers only one score for the entire response of a participant. Regarding PECKI, participants were not required to give responses including different aspects at a time. Therefore, we decided to adapt holistic scoring approach in our study.

In our holistic scoring rubric, we aligned the true answers for an item with their scores. We warned the independent raters about to use these scores at guidelines part of the rubric for a particular question. If a participant's answer included all the true responses/sentences represented in the rubric, this participant's paper was scored as 2 for that item. This procedure was applied for evaluation of the first ten items of the instrument.

For the 15th item, evaluation procedure was different from others. In this item, we wanted participants to write one misconception about current, potential difference, electrostatic force with refutation statements. We aligned all the (teacher-introduced) misconceptions respectively with their refutation statements provided by participant teachers. In this item, all the responses including a misconception were scored as 1. If a participant also refuted the misconception convincingly, his/her answer was scored as 2 for only that concept. Refutation statements were not always scored as 1. They sometimes were scored as 0.5. Types of refutation statements for each of teacher introduced misconception, we encountered in responses, were also presented in the related part of the rubric. Therefore, the maximum score for the 15th item was 6 and for all the items constructed for the first two objectives was 26.

We firstly categorized teachers' responses in accordance to the coding categories to start the scoring of questions of the second component of our instrument (teachers' KIS). This component has the same weight on the total scores of participants as KSUE. KIS contained four different items; hence, each item had a 6.5 maximum score with 26 as maximum total score. Regarding these items, scores were distributed according to whether teachers changed their instructional strategies for repetition of the subject. We observed two different instructional strategies at maximum in each of responses. Therefore, if they did not change their instructional strategies for repetition they got 3.25 point in that item, but if they changed they got 6.5 point.

3.6.1 Rubric for Rating

Scoring open-ended questions poses problems for reliability. Miller, Linn and Gronland (2008) offered several steps to increase the reliability of scoring open-ended questions. These are preparing scoring key, using the most appropriate scoring method, deciding how to handle irrelevant factors, evaluating all answers to one question before going on to the next, scoring the answers without looking at participants' names and obtaining independent ratings. A rubric (see Appendix H), which had two parts, was prepared for evaluation of written responses of participants. First part of the rubric included guidelines about scoring. There were two independent raters in the study, one was the researcher and other was a research assistant (also PhD candidate in the same department) from METU in department of physics education. Therefore, guidelines firstly informed the independent raters about scoring method which was described in next section. Secondly, guidelines warned the independent raters about not to give scores by considering the irrelevant factors such as handwriting, spelling, sentence structure, etc… Finally, guidelines suggested independent raters to evaluate all answers to one question before going to the next. Furthermore, names of participants were not demanded during the data collection, therefore it was not a threat for reliability.

In the second part of the rubric, there was a scoring key. Scoring key was constructed based on participants' answers obtained via third implementation, because this version of PECKI is very similar to the final form. Then, the scoring key was modified based on views of the co-supervisor and two research assistants in physics education department. In addition to this, papers of final implementation were also revised to extend the right answers scope of the rubric.

3.7 Analysis of Data

Analysis included several steps in this study. First of all, we prepared the rubric based on the written responses of teachers. We created the rubric which included the categories of correct answers obtained from the last two administration of PECKI. Each teacher's paper was scored according to this rubric. All the scores were entered on Statistical Package for the Social Sciences (SPSS). Then, descriptive statistics and some of the statistics for validity and reliability analysis and principal component factor analysis were conducted on SPSS. In next step, confirmatory factor analysis including only PECKI items followed by confirmatory structural equation modeling including all variables of the study were conducted on AMOS program.

3.7.1 Validity and Reliability Evidences

Validity is the most important characteristic for assessment studies to make sure that one makes accurate interpretations based on data of the survey. Fraenkel and Wallen (1996) stated that "validity refers to the appropriateness, meaningfulness and usefulness of the inferences a researcher makes" (p. 152).

At the beginning of the analysis, we firstly scored teachers' responses to the KSUE items of PECKI according to the rubric explained in detail in Section 3.6. Weight of each correct response for an item represented in the rubric were determined by detailed discussion among two research assistants, the researcher and the co-supervisor. Refutation sentences' scores were also determined with regard to the convincing power by the same group of researchers.

We selected second item to give some details about coding of teachers' responses since this item has the maximum variation in teachers' responses. In the second item (see Appendix D), we presented teachers with a student learning difficulty from electrostatics. Table 3.4 shows the correct responses presented in the rubric and alternative responses that teachers provided as their answers for this item.

Table 3.4 Example of the Match between Teachers' Alternative Responses and the Correct Responses Presented in the Rubric for Item 2

Correct Responses Presented in the Rubric	**Alternative Responses Given by Teachers Accepted as Correct***
Students know how the charges are distributed only accordance to the radii.	a) They only focus on the radiuses. b) Radiuses of the objects are affecting their response. c) Because of the radiuses.
They confuse charging by induction with charging by contact. They think that charging by induction affects the type of objects' charges, but since the objects touch each other they think that charges distribute among the objects according to the charging by contact rules.	a) They do not know which type of charging rules should be applied on the objects: charging by induction or contact b) The objects in the figure are touching each other and the positively charged stick is getting closed them which causes students to apply both types of charging rules: by induction and by contact. c) They confuse when charged by contact or charged by induction rules should be applied on objects.
They could not consider touching conductive objects as a whole.	a) They think that two conducting objects should be handled as separated even if they are touching each other.
They ignore the principle of conservation of charges.	a) They do not know the principle of conservation of charges. b) They do not know when the principle of conservation of charges should be applied.
They might have thought that stick gets in touch with the object and that the charges should be conserved.	a) They might think that stick touched to the object. However, the objects have to be charged opposite to each other because of the principle of conservation of charges.

*Alternative responses provided by the participant teachers included also the correct responses presented in the left column.

While the second correct response was scored as 1.00 point, others were scored as 0.25 in this item. Because, while the second correct response directly results in the student learning difficulty focused in that item, other responses given by teachers do not alone directly result in the same difficulty. Teachers' scores for the first ten items changed, naturally, in accordance with the number of correct responses they gave. Total score of a participant for an item was calculated by summing up the weighted points given in the rubric for each of the correct response included in his/her answer.

Following the rubric preparation, we constructed the coding categories based on the participants' responses to the KIS items. With the last research question of the study, our main aim was to categorize instructional strategies teachers utilize to remedy/overcome student difficulties/misconceptions. To make this categorization, we had to find all the instructional strategies from the literature or find studies including all these instructional strategies. Schroeder et al. (2007) conducted a meta-analysis study to grasp the effects of instructional strategies on student achievement in science education. They categorized all instructional strategies into ten different groups. We used four of their groups as the basis for coding categories in this study. The main reason for using only four groups is the distribution of instructional strategies provided in participating teachers' responses. That is, the remaining 6 groups in Schroeder et al's study were not observed in teachers' responses. However, we added one more group, 'conceptual change strategies,' which was not in Schroeder et al.'s original 10. At the end, we had a total of five instructional strategies to be used as the codes in qualitative analysis of the items written for the last objective in the table of test specification. Table 3.5 shows these coding categories with their descriptions.

Table 3.5 Coding Categories (adapted from Schroeder et al., 2007, p. 1446-1447)

Codes (Names of the teaching strategies)	Description of the codes
Inquiry strategies	Teachers use student-centered instruction that is less step-by-step and teacher-directed than traditional instruction; students answer scientific research questions by analyzing data
Enhanced context strategies	Teachers relate learning to students' previous experiences or knowledge or engage students' interest through relating learning to the students'/school's environment or setting
Direct instruction	Teachers deliver information verbally or explicitly guide students through a sequence of tasks
Cooperative learning strategies	Teachers arrange students in flexible groups to work on various tasks
Conceptual change strategies	Teachers try to detect and overcome students' misconceptions by classroom implementations

The descriptions and appropriateness of these codes to the study were also checked by three physics educators. In order to provide additional validity evidence for the coding of the data, we included the original written responses from our implementation in Appendix I.

Fraenkel and Wallen (1996) states that there are three types of evidences for validity: content-related evidence, criterion-related evidence and construct-related evidence. First one is match between content of the test and the content of the relevant domain to be assessed. Second one is made by comparing participants' performances on the developed survey with another measure or instrument's scores. Last evidence needs to hypothesize construct in detail and to test hypotheses both logically and empirically. Content-related evidence was collected by taking views of physics educators and PhD candidates as stated in Section 3.3.1

For construct-related evidence of validity, we conducted firstly exploratory and then confirmatory factor analyses to investigate whether the 11 items of first two objectives (belonging to the component of KSUE) and the 4 items of the last objective (belonging to the component of KIS) of the instrument are constituting different constructs or not. First ten items of the instrument were written for the first objective in table of test specifications (see Table 3.3), and the last item was written for the second objective. There were two different reasons of why we focused only on one factor instead of two for these eleven items, although we had two different objectives. Firstly, if we tried to get two different factors, the second factor would have only one item. Secondly, these two different objectives belong to the same component of PCK, namely KSUE. Consequently, treating these 11 items as member of the same factor would not be a problem.

Furthermore, we conducted a confirmatory structural equation modeling to observe the relationships among teachers' PCK and their JS level, PSE level, specific experiences, years of teaching experience and number of attendance to in-service training seminars related to physics teaching program. Results of the two factor analyses and the confirmatory structural equation modeling were used as evidence for construct-related validity. Details of the analyses were provided in the next chapter.

Reliability is defined as "the extent to which a measure yields the same scores across different times, groups of people, or versions of the instrument" (Vanderstoep & Johnston, 2009, p. 83). For JSI and PSEI, internal consistency reliability was represented by Cronbach alpha coefficient.

Cronbach alpha coefficient was not applicable for PECKI scores due to inequality in scoring ranges. Therefore, for PECKI inter-rater reliability was calculated. Vanderstoep and Johnston (2009) mentioned that a measurement has high inter-rater reliability when two researchers agree on characteristics of observed behaviors. Coffman (1971) offered to estimate the reliability by obtaining Pearson product-moment correlation between raters. The researcher and a PhD candidate studying in physics education programme at METU scored the KSUE items independently following the final administration of the PECKI. In this regard, product-moment correlation was estimated by evaluation of 25 randomly selected papers, which amounts to a 20% of all the papers. Utilizing the rubric during evaluation of the papers strengthened the possibility of getting a high inter-rater reliability. Vanderstoep and Johnston (2009) stated that inter-rater reliability coefficients in range of 0.80 to 1.00 are indicators of high inter-rater reliability. We decided the researcher to evaluate all the papers alone if we would estimate the inter-rater reliability coefficient as 0.8 or above.

Reliability of coding conducted on the KIS items was also controlled with inter-rater reliability processes. 25 papers were evaluated by the researcher and a research assistant (from METU), then we calculated percentage of agreement between evaluations of these independent raters. We divided twice of the number of matched observations to total number of observations, and then multiplied this value by 100 (Neuendorf, 2002).

3.7.1.1 Factor Analyses and Structural Equation Modeling

We firstly conducted exploratory factor analysis including solely PCK items on SPSS. Considering the results of this step together with content-related evidence for validity provided by two physics educators and two PhD candidates, we conducted confirmatory factor analysis and confirmatory structural equation modeling (SEM) by utilizing AMOS on our data. This analysis had several steps to follow. First of all, we proposed models presented in Figure 3.1 and Figure 3.2 to test and collect construct-related evidence for validity. These models were the result of the literature.

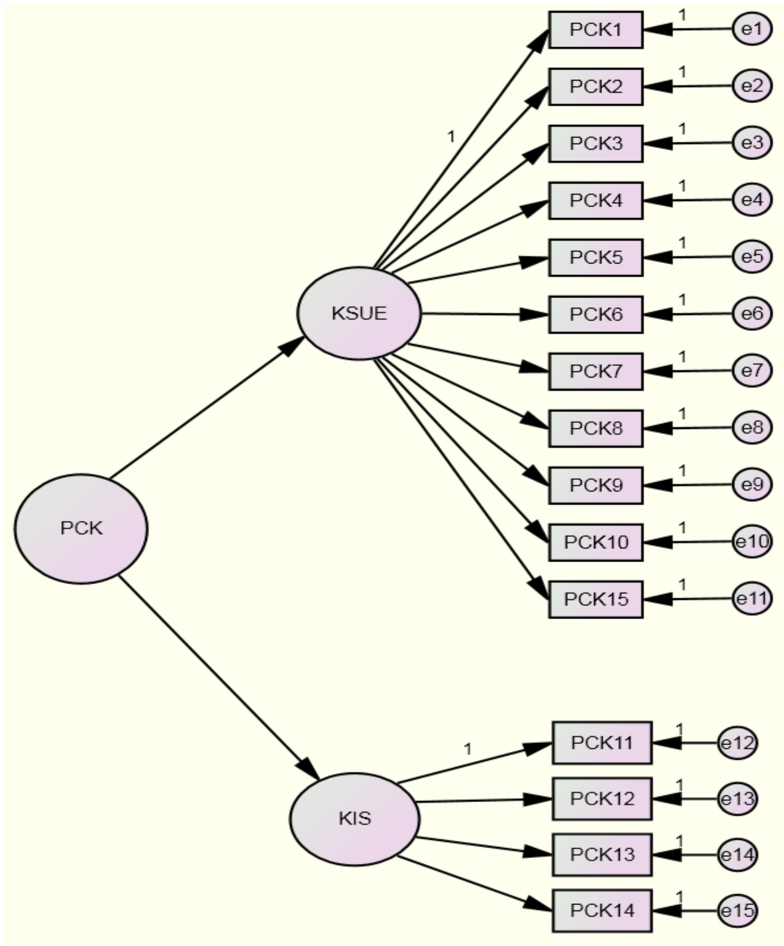


Figure 3.1 Proposed Model Including PCK Dimensions of the Study

Exploratory and confirmatory factor analyses were actually conducted to determine which items should be included in the SEM study. In the proposed models teachers' years of teaching experience, specific experiences regarding students' learning difficulties and misconceptions presented in items, PSE level, JS level and in-service training attendance were utilized as the predictors of PCK. The main difference between these models is the indirect prediction of teachers' PSE level on their PCK in mediation of JS. At the beginning of our study, we constructed proposed model II as the single model of our study; however some studies showed that teachers' PSE has a direct effect on their JS. This relationship between teachers' JS and PSE forced us to construct the proposed model I presented in Figure 3.2.

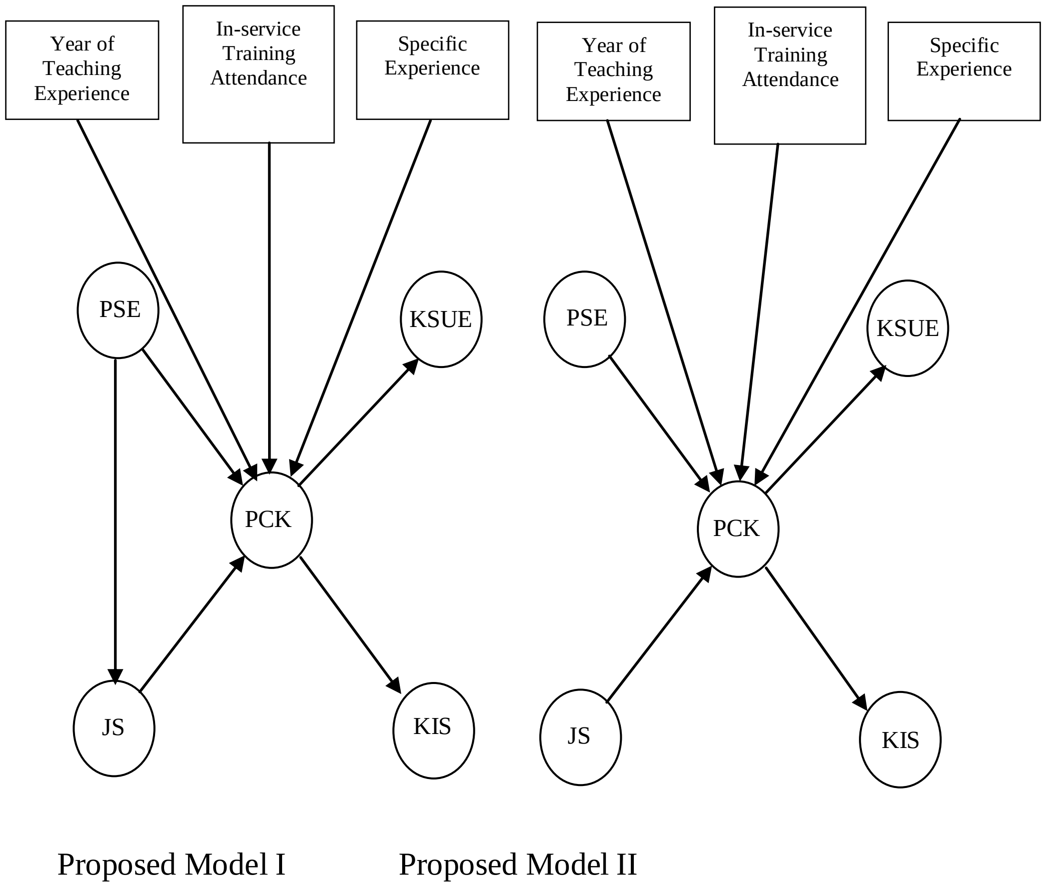


Figure 3.2 Proposed Models Including all Variables of the Study

SEM is a tool representing the relations among all the variables placed in the proposed model. Variables in a model can be divided into two different categories: latent and observed variables. Latent variables are the theoretical constructs that cannot be observed directly. Latent variables are generally constructs or behaviors we intend to measure. Being unable to measure latent variables directly leads researchers to make the measurement on observed variables such as test items (Byrne, 2010).

SEM analysis shows the relations between latent and observed variables via standardized regression weights (factor loadings). We checked significance of these relations among variables together with their values in this second step. Even though AMOS set a default value of 0.001 for the significance level, we interpreted the results against a significance level of 0.05. Additionally, standardized regression weights below 0.4 were accepted as poor measures of the latent variables. Following the second step, we started the evaluation process of model fit. First of all, chi-square (χ^2) value with significance analysis was checked. Byrne (2010) stated that χ^2 statistics is affected by sample size strongly and additionally offered to utilize χ^2 per degrees of freedom (df) known as CMIN/df. She mentioned that CMIN/df values smaller than 2 represents a good fit of data. This procedure gives a quick overview of model fit to researchers. Even though researchers obtain a CMIN/df smaller than 2, some other fit indices should be controlled in the research studies to avoid misinterpretation of data (Byrne, 2010), such as root mean square error of approximation (RMSEA), Goodness-of-Fit Index (GFI), Tucker-Lewis Index (TLI) and Comparative Fit Index (CFI). In our analysis, we also checked all of these indices.

RMSEA relates with the error of approximation in the population and asks the question "How well would the model, with unknown but optimally chosen parameter values, fit the population covariance matrix if it were available?" (Browne & Cudeck, 1993, pp. 137–138 as cited in Byrne, 2010). Browne and Cudeck (1993) mentioned that RMSEA values smaller than 0.05 can be accepted as good fit indicators, and RMSEA values ranging from 0.05 to 0.08 represent reasonable errors of approximation (fair fit) in the population, values ranging from 0.08 to 1.00 indicate mediocre fit and the values larger than 1.00 indicate poor fit.

GFI represents the relative amount of variance and covariance in observed variable scores. As an absolute index GFI compares the proposed model with no model at all (Byrne, 2010). GFI gets values ranging from 0 to 1.00. 0.90 or higher values are indicators of good fit. Finally, TLI and CFI represent how much the proposed model described sample data adequately. TLI and CFI values range from 0 to 1.00. Values higher than 0.90 are indicators of good fit (Byrne,2010).

3.8 Limitations of the Study

In this study, we developed PECKI, which consists of 13 open-ended items regarding concepts related to electricity. The first limitation of the study was the scope of focused concepts within electricity. In the first implementation, 30 participants were asked to write the most difficult concepts related to electricity and their students' learning difficulties and misconceptions. Therefore, mainly these 30 teachers' responses to our questions determined the scope of PECKI. In this respect, we want to stress that PECKI does not focus on all the concepts in electricity.

Another limitation was about the rubric prepared in this study. The rubric was prepared based on the participant teachers' responses and specified the distribution of scores to the cases. If the rubric was prepared based on the findings stated in the literature, we might have attained different scores to teachers' correct responses. This would not change the distribution of teachers' scores but most probably affect adequacy of the responses.

Another limitation was related to the number of participants. 124 teachers participated in the final implementation of the study. Teachers mostly avoid assessment of their knowledge and have a reluctance related to participation in such tasks. Therefore, we could not study with a high level of participation. Principally, 124 participants are enough for a survey study. However, CFA and SEM studies need more participants for more valid results.

The final limitation of the study included qualitative analysis which was implemented mainly on the 4 items in dimension of KIS. We gathered data from the participants only with our instrument. In this situation, we encountered some problems regarding reliability, because we sometimes could not understand whether a participant teacher has the intention to implement all the requirements of an instructional strategy. Moreover, we did not collect observational data from classroom environment. Therefore, we are not sure whether participants implement the strategies stated on their responses in their instructional practices.

3.9 Assumption

Assumption of the study is that participating physics teachers have answered PECKI sincerely.

CHAPTER 4

RESULTS

In this study we had three main research problems. The first research problem of the study was to establish acceptable validity and reliability estimates for an instrument developed to measure knowledge of students' understanding of electricity and knowledge of instructional strategies components of high school physics teachers' PCK related to the teaching of electricity. The research hypotheses are:

1) High school physics teachers' years of teaching experience have a positive, direct effect on their PCK.
2) High school physics teachers' specific experiences have a positive, direct effect on their PCK.
3) High school physics teachers' PSE level has a positive, direct and indirect effect on their PCK.
4) High school physics teachers' JS level has a positive, direct effect on their PCK.
5) High school physics teachers' attendance to in-service training seminars on the physics teaching programs has a positive, direct effect on their PCK.

First research problem of the study together with its research hypotheses needs to portray the details regarding the validation processes of the instrument including exploratory and confirmatory factor analyses together with physics educators' suggestions on items' content and SEM study on the data provided by the PECKI. Therefore; this chapter begins with giving the details of validation processes together with some descriptive information at the final part.

The second research problem is related to the assessment of high school physics teachers' knowledge about students' pre-instructional thinking and misconceptions in electricity. The research question related to this problem is formulated as:

> What is the level of high school physics teachers' knowledge about students' pre-instructional thinking and misconceptions in electricity?

The third research problem is also related to the assessment of teachers' PCK, but this time on the component of teachers' knowledge of instructional strategies related to the teaching of electricity. The research question related to this problem is formulated as:

> What are the teaching strategies implemented by high school physics teachers to overcome student learning difficulties and misconceptions in teaching of electricity?

Following parts of this chapter provided the survey results of the study in answering the second and third research problems. Scoring of participant teachers' responses were realized based the rubric developed in study. Final part of this title presents the summary of overall results.

4.1 Validation of the Pedagogical Electricity Content Knowledge Instrument

This part of the chapter provides information about validation processes of the study including exploratory and confirmatory factor analysis and confirmatory structural equation modeling. Additionally, we gave the details of results' reliability both for the PECKI and other instruments utilized in the study which were PSEI and JSI.

4.1.1 Exploratory Factor Analysis

To conduct exploratory factor analysis, Measures of Sampling Adequacy (MSA) values and anti-image correlations should be greater than 0.50. These values were acceptable in our study. Table 4.1 shows Kaiser-Meyer-Olkin (KMO) measure of sampling and the Bartlett's test of sphericity for item scores. KMO value was found as 0.94 and p-value was found as 0.000 as seen Table 4.1; they are acceptable values.

Table 4.1 SPSS Output Showing KMO and Bartlett's Test for Item Scores

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.935
Bartlett's Test of Sphericity	Approx. Chi-Square	1538.758
	df	105
	Sig.	.000

Moreover, to conduct exploratory factor analysis, each item's communality value must be equal to or above 0.50. Table 4.2 shows the SPSS output presenting items' communality values which were observed as more than 0,50. Therefore, we did not remove any item from the analysis. In addition to this, cumulative percent of variance accounted for was found as above 73%. As a result, three factors were obtained. Table 4.3 shows the items in each factor.

Table 4.2 SPSS Output Showing Communalities

	Initial	Extraction
Item 1	1.000	.743
Item 2	1.000	.816
Item 3	1.000	.740
Item 4	1.000	.752
Item 5	1.000	.697
Item 6	1.000	.883
Item 7	1.000	.939
Item 8	1.000	.788
Item 9	1.000	.809
Item 10	1.000	.847
Item 11	1.000	.696
Item 12	1.000	.530
Item 13	1.000	.641
Item 14	1.000	.560
Item 15	1.000	.630

Extraction Method: Principal Component Analysis.

Table 4.3 SPSS Output Showing Rotated Component Matrix for PCK Items

	Component		
	1	2	3
Item 1	.810		
Item 2	.849		
Item 3	.796		
Item 6	.901		
Item 7	.922		
Item 8	.841		
Item 9	.857		
Item 10	.876		
Item 12	.512	.483	
Item 11		.793	
Item 13		.677	
Item 14		.670	
Item 15	.272	.712	
Item 4			.867
Item 5			.824

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a Rotation converged in 3 iterations.

According to Table 4.3, Items 1, 2, 3, 6, 7, 8, 9, 10 and 12 formed the first factor, Items 11, 13, 14 and 15 formed the second factor and Items 4 and 5 formed the third factor. Interpretation of the first factor includes only one aspect (objective) of the PCK component (knowledge of students' understanding of electricity) except for the Item 12 which was constructed for the second component of PCK (knowledge of instructional strategies). On the other hand; second factor included the last item of the instrument which was constructed for KSUE component of the instrument. Other items of this factor corresponded to KIS component. Furthermore, Items 4 and 5 seemed to form another factor different from what we looked for in the first objective. As a result, first two factor's interpretation has not exactly parallel content with what we intended. However, based on the views and suggestions of two physics educators and two PHD candidates requested for content-related validation purposes; we decided to include all the 15 items of PECKI in confirmatory factor analysis.

4.1.2 Confirmatory Factor Analysis Results of PECKI Items

CFA was conducted by utilizing AMOS program on our proposed CFA model (see Figure 3.1). In our CFA study, while PCK, KSUE, and KIS were the latent variables, items in PECKI were chosen as observed variables. In CFA, standardized regression weights (factor loadings) were used to show the relation between latent and observed variables. Table 4.4 shows the initial results including completely standardized solution for PECKI item set.

Table 4.4 Initial Results for Factor Loadings and Measurement Errors

	Item	FL	ME	p
KSUE	Item 1	.85	-	< .05
	Item 2	.90	.07	< .05
	Item 3	.83	.07	< .05
	Item 4	.06	.13	> .05
	Item 5	.19	.09	< .05
	Item 6	.93	.06	< .05
	Item 7	.97	.06	< .05
	Item 8	.87	.07	< .05
	Item 9	.88	.06	< .05
	Item 10	.90	.07	< .05
	Item 15	.50	.27	< .05
KIS	Item 11	.54	.26	< .05
	Item 12	.62	.27	< .05
	Item 13	.65	.30	< .05
	Item 14	.47	-	< .05

The regression weight for KSUE in the prediction of Item 4 is not significantly different from zero at the 0.05 level, so this item was deleted from the model. There is not a globally accepted cutoff value for factor loadings. In this study, standardized regression weights below 0.4 were accepted as poor measures of the latent variables. Item 5 whose factor loading was found as 0.19 was omitted from the model. Then, we conducted the analysis again for the remaining 13 items. Table 4.5 shows the final results for factor loadings together with measurement errors.

Table 4.5 Final Results for Factor Loadings and Measurement Errors

	Item	FL	ME	p
KSUE	Item 1	.85	-	< .05
	Item 2	.90	.07	< .05
	Item 3	.83	.07	< .05
	Item 6	.93	.06	< .05
	Item 7	.97	.06	< .05
	Item 8	.87	.07	< .05
	Item 9	.88	.06	< .05
	Item 10	.90	.07	< .05
	Item 15	.50	.27	< .05
KIS	Item 11	.49	.26	< .05
	Item 12	.61	.27	< .05
	Item 13	.62	.29	< .05
	Item 14	.48	-	< .05

Factor loadings and measurement errors were almost not affected from item elimination. Standardized regression weights observed between PCK and KSUE and between PCK and KIS was found as 1.00.

Following this step, we focused on fit index values of the model. First of all, we obtained a chi-square (χ^2) value of 128.054 with 65 degrees of freedom (df) and a probability of level 0.000. Because of probability level, we had to state that fit of the data to the model is not adequate; however, Byrne (2010) states that χ^2 statistics have limitations because of its' sensitiveness to the sample and model size. The author suggested to utilize CMIN/df value instead of χ^2 statistics. Therefore, our decision is that the fit of the data to the model is adequate, since χ^2 and df values were comparable (CMIN/df=1.970) and supported the tested model.

Additionally, we checked the other fit indices for evaluation of the goodness-of-fit of the model in the second step. These fit indices were RMSEA, GFI, TLI and CFI. Table 4.6 shows the values of selected fit indices with cutoff criteria.

Table 4.6 Fit Indices of CFA

Fit Index	Value	Cutoff Criteria	Satisfaction
CMIN/df	1.970	< 2.00	Satisfied
RMSEA	0.089	< 0.05	Unsatisfied
GFI	0.847	> 0.90	Unsatisfied
TLI	0.948	> 0.90	Satisfied
CFI	0.957	> 0.90	Satisfied

RMSEA had a value of 0.089 which cannot be admitted as a good fit index value. Browne and Cudeck (1993, as cited in Byrne, 2010) stated that RMSEA values ranging from 0.05 to 0.08 indicate fair fit, values ranging from 0.08 to 1.00 indicate mediocre fit and the values larger than 1.00 indicate poor fit. Therefore, we found that our model with a RMSEA value of 0.089 represents a mediocre fit for our data.

GFI value was found as 0.847 which is smaller than the cutoff criteria for a good fit. GFI can have values ranging from 0 to 1.00 and values closer to 1.00 are indicator of good fit. In this regard, our GFI value represents fair fit of data to the tested model. Finally, TLI value of 0.948 and CFI value of 0.957 implies good fit of data to the model.

At first glance, the RMSEA and GFI indices being outside the cutoff criteria seem problematic. Boomsma (2000) stated that in CFA and SEM studies, researchers need hundreds of subjects. 124 physics teachers participated in our study and this inadequacy in sampling was the main reason for why we found the RMSEA and GFI indices values outside of the cutoff criteria.

In conclusion, Items 1, 2, 3, 6, 7, 8, 9, 10 and 15 were included in the first factor (KSUE), and Items 11, 12, 13 and 14 were included in the second factor (KIS) for the subsequent analysis as can be seen in Table 4.2. Deleting Items 4 and 5, two items related to electrostatic were also omitted from PECKI which has two more items related to this concept in KSUE factor. Therefore, interpretation of the first factor includes two objectives constructed for the test items (see Table

2.1). As a result, both factors' interpretations have a parallel content with what we intended at the beginning. Results also imply that PCK included 13 open-ended items in confirmatory SEM analysis whose results represented in next section.

4.1.3 Confirmatory Structural Equation Modeling Results

Confirmatory SEM analysis, including all variables, was conducted by utilizing AMOS program upon deciding which PECKI items should be placed in full item set based on CFA results. There were two proposed models (see Figure 3.2), in which teachers' PSE and JS level, years of teaching experience, specific experiences and in-service training attendance related to physics teaching programs were placed as predictors of teachers' PCK, to be tested in the study.

Model fit indices of both models in Table 4.7, the Maximum Likelihood test results of the proposed model I in Figure 4.1 and the ratio of variance explained by the models showed that the proposed model I fits more appropriately than the model II for the present study's data.

Table 4.7 Fit Indices of the Proposed Models

Fit Index	Proposed Model I	Proposed Model II	Cutoff Criteria
Chi-square	740.087 ($p<0.05$)	952.993 ($p<0.05$)	-
CMIN/df	1.612	2.072	< 2.00
RMSEA	0.071	0.093	< 0.05
GFI	0.751	0.717	> 0.90
TLI	0.922	0.863	> 0.90
CFI	0.928	0.873	> 0.90

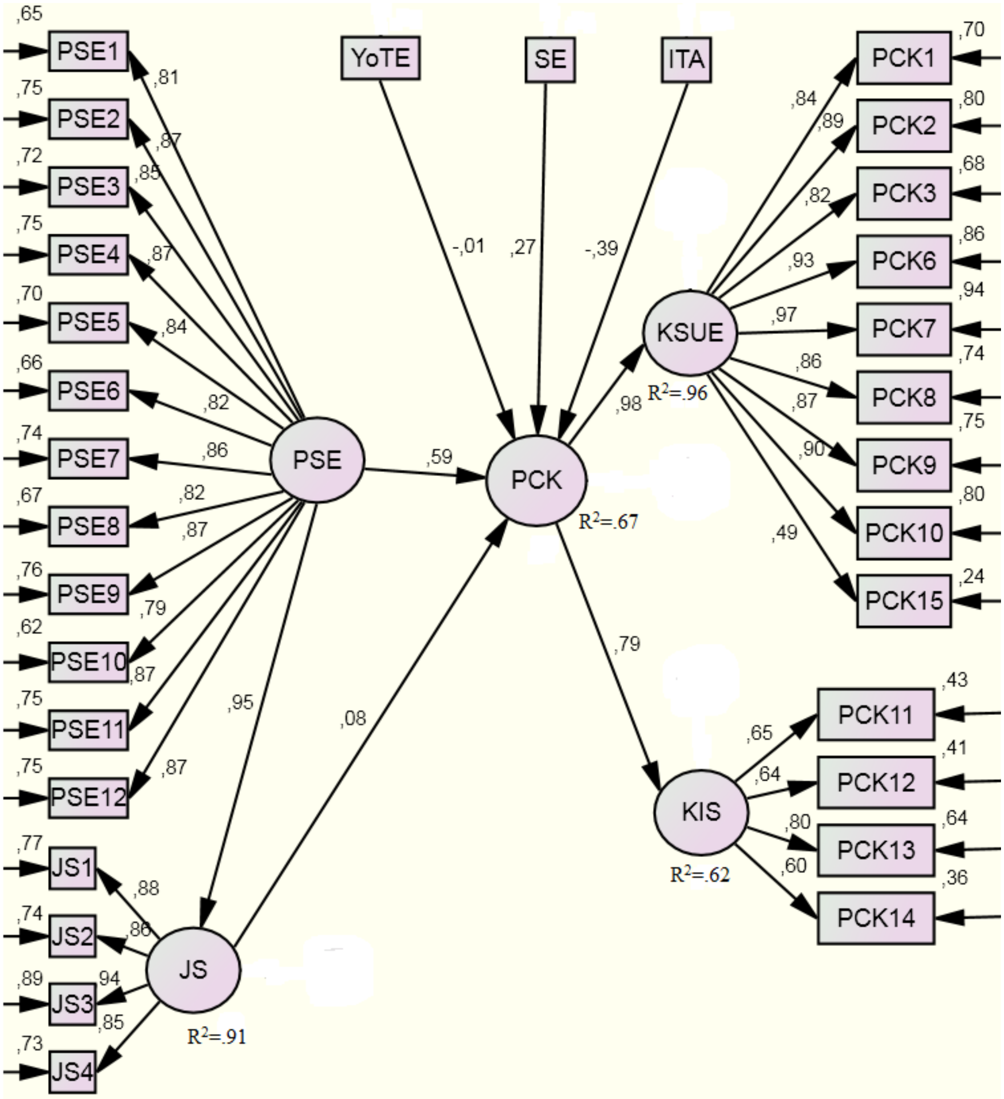


Figure 4.1 The Maximum Likelihood Test Result of the Proposed Model I (YoTE: Year of teaching experience, ITA: In-service training attendance, SE: Specific experience.)

Besides of model fit indices values, there are two main reasons to opt for the proposed model I rather than the proposed model II. Firstly, the proposed model I enabled us to compare PSE's direct and indirect effects on PCK. For determining indirect effect of PSE, we used a mediation analysis where JS was a mediator in the relation between PSE and PCK. Mediation analysis showed that the coefficient representing PSE's indirect effect was 0.07. The regression coefficient representing PSE's direct effect was 0.59; whereas same coefficient representing JS's direct effect was 0.08. These evidences also proved that JS' direct prediction on physics teachers' PCK was negligible. However, in the proposed model II we found JS's direct effect on PCK as 0.19. Secondly, while proposed model I explains the 67% of the variance regarding PCK, proposed model II explained 61% of this variance. Therefore, we continued with proposed model I for the rest of our analysis.

According to Table 4.4, we found the χ^2 value as 740.087 with 459 degrees of freedom and a probability level of .000. χ^2 and df values were comparable (CMIN/df=1.612) and supported the proposed model I. In this regard, we can state that the fit of data is adequate.

RMSEA had a value of 0.071 indicating a fair fit of the data. In addition to this, GFI had a value of 0.751 for the proposed model I implying fair fit. Finally, TLI value of 0.922 and CFI value of 0.928 implies good fit of data to the model.

According to Figure 4.1, all predictors significantly predicted PCK except for teachers' JS and years of teaching experience. The most powerful predictor was PSE, followed by teachers' in-service training attendance regarding physics teaching programs and specific experiences. According to significant relations, the teachers who have higher perceived self-efficacy beliefs, more specific experiences and attended smaller number of in-service training seminars have better PCK. Even though former two relations were expected results, the negative relation between PCK and teachers' in-service training attendance needs further attention. Although the attendance of in-service training activities regarding physics teaching programs has a potential to positively predict PCK, the negative relation in the present study can be explained by irrelevancy of these seminars' content to the teachers' PCK regarding teaching of electricity and the reluctance of the participants, who frequently attend in-service training seminars, about adequately filling the instruments. The in-service training seminars in Turkey are considered as suitable contexts by most of the educational researchers in order to collect data perhaps because of availability of considerable number of teachers. In this regard, it is possible that many of the teachers who attended in-service training seminars might have also participated in research studies by filling out forms/surveys similar to the one used in this study. Therefore, particularly the ones who, at the time of data collection, were attending the in-service training seminars might have already been bored with such activities, and filled the instruments reluctantly. 81 of the participants filled the related part on the instrument which was asking participants to write their survey response time. Survey response time was changing between 20 minutes to 90 minutes with average of 48 minutes. This response time might have increased the reluctance of participants from the in-service training seminar. When we investigated the instruments filled by the participants, we detected that responses of the participants of the in-service training were shorter and insufficient in according to the other participants. This might have resulted in low PCK scores for those reluctant teachers thereby flipping the positive relationship to a negative one between in-service training attendance and PCK.

As a result, we tried to develop and validate PECKI consisting of high school physics teachers' PCK in two dimensions regarding teaching of electricity to do what is necessary for first main research problem of the study. There were also five research hypotheses, utilized in validation of instrument, under this main research problem.

Based on the confirmatory SEM results, the first research hypothesis of the study is that high school physics teachers' years of teaching experience have a positive, direct effect on their PCK and the last research hypothesis is that high school physics teachers' attendance to in-service training seminars on the physics teaching programs has a positive, direct effect on their PCK did not produce expected results. Results showed that teachers' years of teaching experience have no effect on their PCK. In addition, in-service training attendance has a negative effect on teachers' PCK. Therefore, decision was not to reject first and last null hypotheses. The second research hypothesis that is high school physics teachers' specific experiences have a positive, direct effect on their PCK satisfied our expectations, since we found that specific experiences have a positive and significant prediction on PCK at 0.05 level of significance. Therefore, decision was to reject second null hypothesis. Furthermore, the third research hypothesis is that high school physics teachers' PSE level has a positive, direct and indirect effect on their PCK and the fourth research hypothesis is that high school physics teachers' JS level has a positive, direct effect on their PCK partially supported our expectations. Results showed that teachers' PSE and JS level had a positive and direct effect on their PCK; however, the prediction of JS was not significant. Therefore, indirect prediction of teachers' PSE level on their PCK in mediation JS was not also significant. Therefore, decision was to reject third and fourth nul hypotheses.

4.1.4 Inter-rater Reliability in Scoring and Coding

We calculated two different inter-rater reliability scores, one for the scoring in KSUE items and the other for coding of KIS items. As we stated in our previous chapter, inter-rater reliability in scoring was calculated by controlling Pearson product-moment correlation (*r*) between scores of two independent raters. Responses of 25 papers (randomly selected among all papers) were evaluated utilizing the rubric. Responses of first ten items and the last item were evaluated by the raters. Then, *r* was calculated on SPSS. Value of *r* was found as 0.86 which was indicator of moderately high inter-rater reliability.

Inter-rater reliability in coding was controlled by calculating percentage of agreement between two independent raters' coding. At the beginning of the process, the raters had close but different total number of observations. The main reason of this problem was the group of sentences matching with codes. We discussed where the finishing points of a few groups of sentences were. Following the discussion, raters evaluated the papers one more time. At the end, we reached to 78% score of inter-rater reliability in coding.

4.1.5 Reliability of Perceived Self-Efficacy and Job Satisfaction Scores

Cronbach alpha reliabilities of PSE and JS scores were calculated as 0.96 and 0.93 in the study. Caprara et al. (2003) found the cronbach alpha reliability for PSE and JS scale as 0.74 and 0.82 respectively. The study was including 2688 high school teachers. In another study, using the same instrument with a of a total of 500 elementary and high school teachers from Canada, Korea (South Korea or Republic of Korea), and the United States Klassen et al. (2010) found the reliability of the JS scale as 0.83 (for Canadian teachers), 0.87 (for Korean teachers), and 0.83 (for USA teachers) respectively. We found the higher scores of reliability for PSE and JS scale than the previous researchers.

4.1.6 Descriptive Statistics

We presented descriptive results of the study variable by variable under this title.

4. 1.6.1 Teachers' Perceived Self-Efficacy Scores

PSE level of participants was measured with 12 (5-point) Likert type items in final implementation. As a result of this, participants got a score out of 60 in this variable. Figure 4.2 shows the distribution of scores in this variable. Table 4.8 also presents some descriptive statistics in this variable of the study.

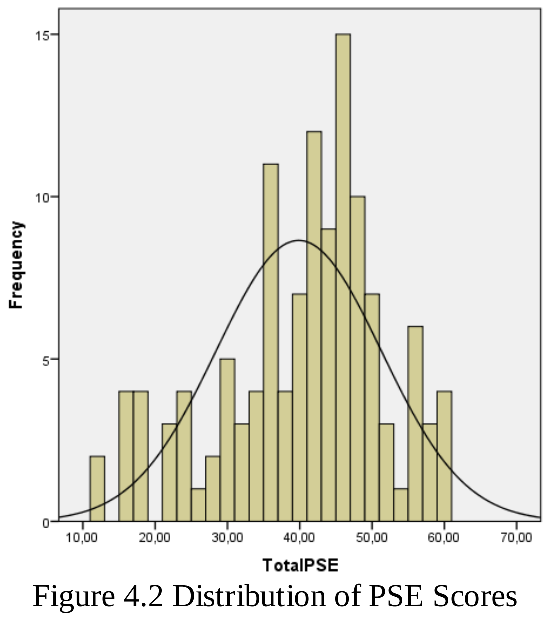


Figure 4.2 Distribution of PSE Scores

Table 4.8 Descriptive Statistics for PSE Scores

	N	Minimum	Maximum	Mean	Std. Dev.	Kolmogorov-Smirnov (Sig.)
PSE	124	12.00	60.00	39.85	11.43	.001

Table 4.8 shows that mean and standard deviation of the scores were found as 39.85 and 11.43, respectively. Total scores representing teachers' PSE level show an approximate normal distribution. While minimum total score was observed as 12, maximum score was observed as 60 for 1 and 2 participants respectively.

4. 1.6.2 Teachers' Job Satisfaction Scores

JS level of participants was measured 4 (5-point) Likert items in final implementation. As a result of this, participants got a score out of 20 in this variable. Figure 4.3 shows the distribution of scores in this variable. Table 4.9 also presents some descriptive statistics in this variable of the study.

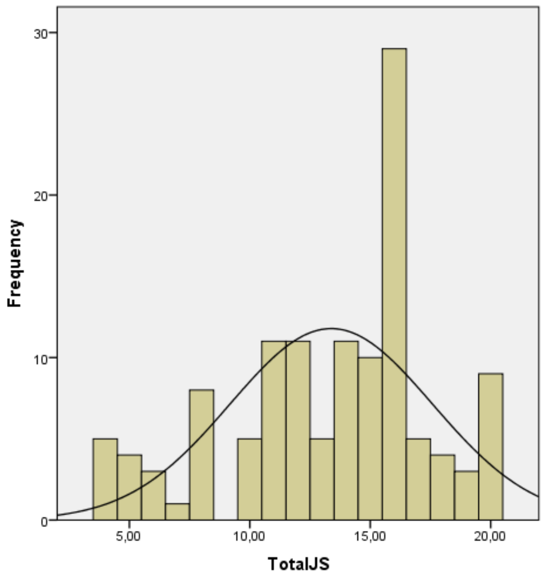


Figure 4.3 Distribution of JS Scores

Table 4.9 Descriptive Statistics for JS Scores

	N	Minimum	Maximum	Mean	Std. Dev.	Kolmogorov-Smirnov (Sig.)
JS	124	4.00	20.00	13.38	13.38	.000

Table 4.9 presents that mean and standard deviation of the scores were found as 13.38 and 4.20 respectively. Total scores representing teachers' JS level show an approximate normal distribution. While minimum total score was observed as 4, maximum score was observed as 20 for 5 and 9 participants respectively.

4. 1.6.3 Teachers' Years of Teaching Experience

Year of teaching experience corresponded to participants' years of professional experiences. Participant teachers were asked to write their years of teaching experience in years at the beginning of the PECKI form. Figure 4.4 shows the distribution of participants' years of teaching experience. Table 4.10 also presents some descriptive statistics in this variable of the study.

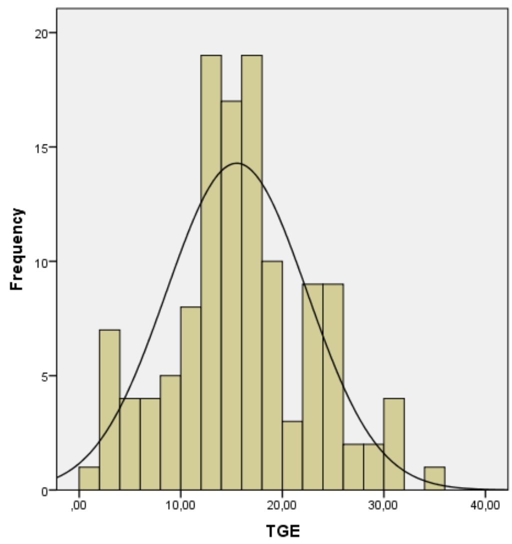


Figure 4.4 Distribution of Participants' Years of Teaching Experience

Table 4.10 Descriptive Statistics for Teachers' Years of Teaching Experiences

	N	Minimum	Maximum	Mean	Std. Dev.	Kolmogorov-Smirnov (Sig.)
TGE	124	1.00	34.00	15.51	6.92	.012

Table 4.10 shows that mean and standard deviation of the scores were found as 15.51 and 6.92, respectively. Participants' teaching experiences in years show an approximate normal distribution. While minimum year of experience was observed as one year, maximum year of experience was observed as 34 for one participant in each category.

4. 1.6.4 Teachers' Specific Experiences

Specific experience score corresponded to whether participants having previously experienced a specific student learning difficulty or misconception in classroom. Participant teachers were asked to mark how they answered PECKI items at the end of each item except for the last one. While teachers who marked experience got one specific experience point, teachers who marked reasoning got zero specific experience point. Therefore, at the beginning of analysis maximum score in this variable was 14; however, Items 4 and 5 were extracted from the dataset as result of CFA of PECKI items. This situation decreased the maximum score in this variable from 14 to 12. Figure 4.5 shows the distribution of participants' specific experience scores. Table 4.11 also presents some descriptive statistics in this variable of the study.

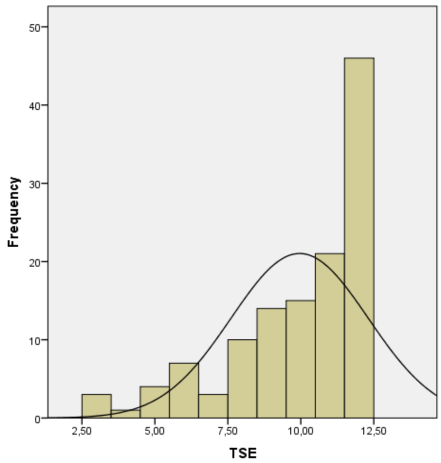


Figure 4.5 Distribution of Participants' Specific Experience Scores

Table 4.11 Descriptive Statistics for Teachers' Specific Experiences

	N	Minimum	Maximum	Mean	Std. Dev.	Kolmogorov-Smirnov (Sig.)
TSE	124	3.00	12.00	9.9597	2.35	.000

Figure 4.5 shows that teachers' specific experience scores show an increasing frequency with high scores. This was an expected result, because the PECKI items were constructed based on teachers' own experiences. However, the distribution is still a normal distribution according to the Table 4.11. While minimum specific experience score was observed as 3, maximum specific experience score was observed as 12 for 3 and 46 participant teachers respectively.

4. 1.6.5 Teachers' In-service Training Attendance

Participants were asked to write their number of in-service training attendance regarding physics teaching programs. 56 teachers from our sample participated an in-service training in Aksaray. We distributed the PECKI forms at the beginning of the training and collected them one day later. Therefore, if a teacher wrote one of his/her training attendance as Aksaray, we extracted that training from his/her attendance list. There were also 8 more in-service trainees out of Aksaray participants. Figure 4.6 shows the distribution of participants' in-service training attendance regarding physics teaching programs. Table 4.12 also presents some descriptive statistics in this variable of the study.

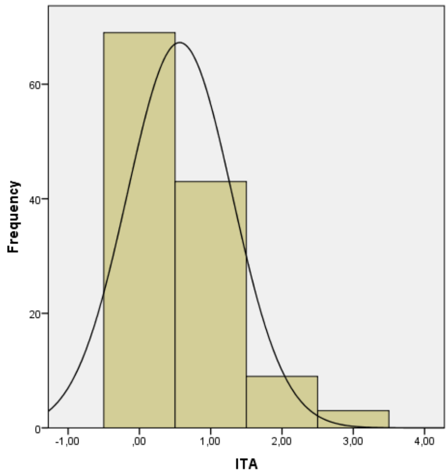


Figure 4.6 Distribution of Participants' In-service Training Attendance

Table 4.12 Descriptive Statistics for Teachers' In-service Training Attendance

	N	Minimum	Maximum	Mean	Std. Dev.	Kolmogorov-Smirnov (Sig.)
ITA	124	.00	3.00	.56	.74	.000

Table 4.12 shows that mean and standard deviation of the scores were found as 0.56 and 0.74, respectively. Figure 4.6 presents that the number of teachers' in-service training attendance is decreasing with an increasing frequency, but the distribution is still a normal distribution according to Table 4.12. This was an expected result since most of the participants of our sample were not trainees in Aksaray. While minimum number of training attendance was observed as zero, maximum number of training attendance was observed as three for 69 and 3 participants respectively.

4.2 Survey Results

In this section, survey results regarding the second and third research problems were presented.

4.2.1 Teachers' Knowledge of Students' Understanding of Electricity

In this section of the study, second research problem of the study, which was related to the assessment of high school physics teachers' knowledge about students' pre-instructional thinking and misconceptions in electricity, was handled.

There were 11 items under this component of PECKI at the beginning of the analysis. Based on the exploratory and confirmatory factor analyses results and two physics educators' suggestions, Items 4 and 5 were discarded from the data set. Therefore, total maximum score available decreased to 22 for the remaining nine items of the KSUE component. Figure 4.7 shows histogram of KSUE scores. Table 4.13 also presents some descriptive statistics in teachers' KSUE scores.

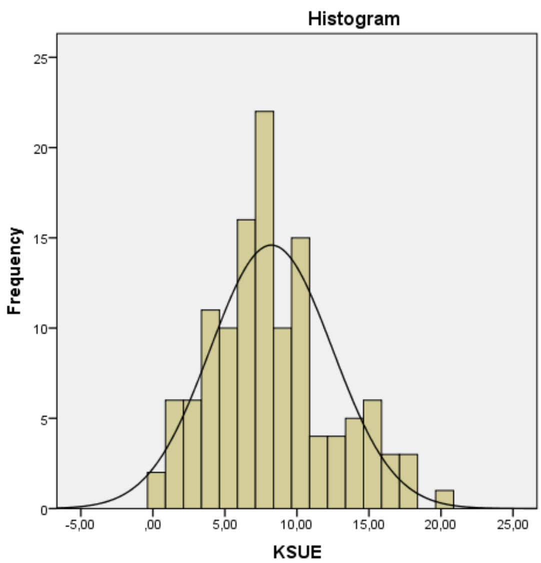


Figure 4.7 Histogram of KSUE Scores

Table 4.13 Descriptive Statistics for Teachers' KSUE Scores

	N	Minimum	Maximum	Mean	Std. Dev.	Kolmogorov-Smirnov (Sig.)
KSUE	124	.25	19.75	8.23	4.24	.024

As seen in Table 4.13, observed scores of participants ranged from 0.25 to 19.75. Mean and standard deviation of the scores were found as 8.23 and 4.24, respectively. Scores are distributed normally as can be seen both from the histogram and Table 4.13. That is, at least half of the teachers seemed to have a limited knowledge about students' pre-instructional thinking and misconceptions in electricity. Also, when examined closely, almost 25% of teachers scored 5 or less, which is a remarkable result of this study.

Eight of the nine remaining items presented teachers with a student learning difficulty or misconception, and then asked which opinions of students would result in that particular learning difficulty or fall in misconception presented in the question. In addition to this eight items, the last item of the instrument asked participants to write three misconceptions (regarding current, potential difference and electrostatic force) with their refutation statements. The rubric (see Turkish version in Appendix H) was prepared based on the participants' responses to these items; therefore, it also represents the variation of answers. The rubric itself presents the answer of second main research problem of the study which is what do high school physics teachers know about students' pre-instructional thinking and misconceptions in electricity? The distribution of teacher responses to Items 1 and 2 are given in Table 4.14.

Table 4.14 Teacher Responses to Items 1 and 2

ITEM 1
a) Students do not know how the charges distribute on a conductor. (0.25) **b)** They do not know or apply the principle of same potential equality for touching conductive objects. (0.25) **c)** Touching a conductive object inside of a hollow conductor and connecting it with a conducting wire to the inside of the hollow conductor are different from each other. Students are not able to distinguish these processes and think the object X is touching the hollow conductor from the inside. (1.50)
Frequency in Observation of Correct Responses for Item 1: a) 80 (46.51%) b) 67 (38.95%) c) 25 (14.53%)

ITEM 2
a) Students know how the charges are distributed only accordance to the radii.(0.25) **b)** They confuse charging by induction with charging by contact. They think that charging by induction affects the type of objects' charges, but since the objects touch each other they think that charges distribute among the objects according to the charging by contact rules. (1.00) **c)** They could not consider touching conductive objects as a whole. (0.25) **d)** They ignore the principle of conservation of charges. (0.25) **e)** They might have thought that stick gets in touch with the object and that the charges should be conserved. (0.25)
Frequency in Observation of Correct Responses for Item 2: a) 91 (35.68%) b) 32 (12.54%) c) 69 (27.05%) d) 37 (14.50%) e) 26 (10.2%)

As can be seen from the distribution of teacher responses, only a small percentage of teacher responses (14.53% for Item 1 and 12.54% for Item 2) can be considered a more complete answer explaining the reason for student difficulty related to the charge distribution and charging respectively. According to the results, teachers mostly think that students have problems with distribution of the charges on conductors and most of the students solely focus on the radii of the conductive objects in distribution of charges. The distribution of teacher responses to Items 3 and 7 are given in Table 4.15.

Table 4.15 Teacher Responses to Items 3 and 7

ITEM 3
a) When the electron passes point B, positive charges at the left side of the sphere pulls the electron with stronger force; whereas when the electron passes point C, positive charges at the right side of the sphere pulls the electron with stronger force in comparison with the positive charges at the other side of the sphere. Therefore, students think that the electron firstly slows down and then speeds up while passing inside of the sphere. (1.00) **b)** They do not know or are not able to apply the principles that inside surface of a hallow sphere is neutral and there is no electric field inside of the sphere. (0.50) **c)** They are not able to think that no electrical force can be exerted on the objects where there is no electric field. (0.50)
Frequency in Observation of Correct Responses for Item 3: a) 28 (20.28%) b) 62 (44.92%) c) 48 (34.78%)
ITEM 7
a) Students are not able to apply the signs of the power supply's terminals on the circuit. (0.25) **b)** They do not know the relation between electric field and type of charges. They think that direction of electric force solely depends on the direction of electric field. (0.75) **c)** The answer for the examples given in the classroom generally occurs as 'to the right'. This situation causes students conditioning to give the same answer. (0.50) **d)** They know the direction of the current as from positive to negative and think that electrons also move in the same direction with current. (0.50)
Frequency in Observation of Correct Responses for Item 7: a) 55 (29.25%) b) 42 (22.34%) c) 57 (30.31%) d) 34 (18.08%)

As can be seen from the distribution of teacher responses, only a small percentage of teacher responses (29.25% for Item 3 and 22.34% for Item 7) can be considered a more complete answer explaining the reason for student difficulty related to electric field. According to the results, teachers mostly think that students cannot apply the principles in electrostatics on spheres and regularity of teachers' examples in classroom also causes students to ignore the changes in similar questions and to response in the same way. The distribution of teacher responses to Items 6 and 9 are given in Table 4.16.

Table 4.16 Teacher Responses to Items 6 and 9

ITEM 6
a) Students are not able to calculate the potentials at either ends of circuit elements. (0.50) **b)** Extraordinary appearance of the circuit and complex connection of the voltmeter to the circuit elements causes students to make mistake. (0.25) **c)** They do not know that voltmeter measures potential difference. Therefore, they are not able to think that potential of the voltmeter's probes should be calculated in Figure II. (0.50) **d)** They think that the voltmeter in Figure I measures not potential difference but potential of the resistance that is connected in parallel to the voltmeter. With the same idea, they try to find the resistor the voltmeter is connected in parallel to in Figure II and they are not able to find the right answer. (0.75)
Frequency in Observation of Correct Responses for Item 6: a) 41 (21.13%) b) 68 (35.05%) c) 53 (27.31%) d) 32 (16.49%)
ITEM 9
a) Students think that the two lamps at above part of the figure share the potential equally since these lamps seem to be on the same branch whereas the lamp at the bottom makes use of the same potential alone. (0.75) **b)** They think that current is divided into two equal parts at the beginning, then it is divided into two equal parts again in the above branch. (0.75) **c)** Seemingly longer path I_3 flows causes students to think that it has to be low. (0.50)
Frequency in Observation of Correct Responses for Item 9: a) 56 (38.09%) b) 48 (32.65%) c) 43 (29.25%)

As can be seen from the distribution of teacher responses, only a small percentage of teacher responses for Item 6 (16.49%), but a higher percentage for Item 9 (70.74%) can be considered a more complete answer explaining the reason for student difficulty related to potential difference respectively. According to the results, teachers mostly think that extraordinary appearance of the figures leads students to apply the principles of potential difference in a wrong manner and students make mistakes regarding the distribution of the potential in a circuit to the lamps. The distribution of teacher responses to Items 8 and 10 are given in Table 4.17.

Table 4.17 Teacher Responses to Items 8 and 10

ITEM 8
a) Students liken the circuit presented on the item to torch and decide the lamp will light. (0.75) **b)** They cannot consider that the lamp too has two poles. They think that the contact between the conducting wire and the lamp is enough for current to flow through the lamp. (0.50) **c)** Drawing the resistance in the form of a lamp prevents them to see that there is not a closed circuit consisting the lamp. They are not able to think that lamp is also a resistance. (0.75)
Frequency in Observation of Correct Responses for Item 8: a) 23 (15.33%) b) 55 (36.66%) c) 72 (48%)
ITEM 10
a) Since students do not know the working principle of a transformer, they think that high potential difference means high current, and therefore they think that there will be more energy loss based on the $P = I^2R$ formula. (1.00) **b)** They think that high potential provides more electrons to flow in the circuit and results an increase in loss of energy due to the friction. (0.75) **c)** They confuse the concepts of voltage and current with each other. (0.25)
Frequency in Observation of Correct Responses for Item 10: a) 32 (22.53%) b) 65 (45.77%) c) 45 (31.69%)

As can be seen from the distribution of teacher responses, a high percentage of teacher responses for Item 8 (63.33%) but a small percentage for Item 10 (22.53% for Item 2) can be considered a more complete answer explaining the reason for student difficulty related to the electric circuits and energy respectively. According to the results, teachers mostly think that students sometimes have problems about making a connection between the principles in electricity and the real life because of the figuration of the circuits. Finally, many students make a connection between the abundance of voltage and loss of the energy in a circuit in a wrong way. Teacher introduced misconceptions about current is given in Table 4.18.

Table 4.18 Teacher Introduced Misconceptions about Current

ITEM 15		
Concept	**Misconception**	**Refutation Statements**
Current	Current is the flow of electrons. (21.29%)	1) It is the influence (vibration) of electrons on each other. Current is the transportation of energy via vibration of electrons. (1.00)
	Electrons move with the	1) Energy spreads out at approximately speed of

Current	speed of light. (13.96%)	light. (0.50) 2) Not the electrons but photons move with speed of light. (1.00)
	Current flows in the same direction with electrons. (16.56%)	1) Current flows from a battery's (+) pole to its (–) pole, whereas electrons flow in the opposite direction. (1.00)
	Current is created by the flow of electrons from (+) pole to (–) pole. (8.87%)	1) Current is created by the flow of electrons from (–) pole to (+) pole. (0.50) 2) Current flows from high potential to low potential if there is potential difference in a closed circuit. (1.00)
	Current starts to flow from both poles of a battery and come into collision on a lamp. (2.65%)	1) Current flows only from (+) pole to (–) pole. (0.50) 2) Electrons flows only from (–) pole to (+) pole as they vibrate. Therefore, current has also only one direction opposite to the electrons. (1.00)
	There is no current inside a battery when connected in a closed circuit. (12.59%)	1) Batteries have also internal resistance, and current flows through it. If current does not flow through internal resistance, the circuit turns into an open-circuit. (0.50) 2) A lamp gets warmer when the current flows through it. Batteries also get warmer after a while and this proves that current flows in batteries. (1.00)
	Current waits at the endpiece of the conducting wire. (4.30%)	1) If conducting wire is an open-circuit's component, not only electrons at the endpiece of the conducting wire but also all electrons belonging to all components also wait and current is not created. (0.50) 2) If there is potential difference in a closed circuit there has to be also current in that circuit, whereas if there is not any potential difference on the circuit, current does not wait, it disappears. (1.00)
	Current is created by flow of the positive charges. (5.54%)	1) Positive charges do not flow. (0.50) 2) Electrons transport the vibration from (–) terminal to (+) terminal; however, there has to be potential difference to create this vibration on the circuit. (1.00)
	Current is used up on the resistor. (7.82%)	1) Electric energy, transported by electrons via current, is transformed into heat, light and/or sound energy. Current does not change since the number of electrons, creating current, does not change. (1.00)
	Potential difference should be changed to create current. (6.42%)	1) There has to be a battery in the circuit to create potential difference and to provide the lamp to give light. In other words, potential difference has to be created for shining. It is not necessary to change the battery continuously. (1.00)

According to Table 4.18 when examined closely, four of the ten teacher-introduced misconceptions seem to be most-recognized student misconception related to electric current, gathering almost 65% of teacher responses. These are the misconceptions that are discussed mostly in the literature: ‘Current is the flow of electrons,’ ‘current moves in the same directions with electrons,’ ‘electrons move with the speed of light,’ and ‘there is no current inside a battery when connected in a closed circuit.’ Teacher introduced misconceptions about potential difference is given in Table 4.19.

Table 4.19 Teacher Introduced Misconceptions about Potential Difference

Potential Difference	Potential difference is the potential of a point. (20.59%)	1) Potential difference is the difference between potentials of two different points. (1.00)
	Potential difference flows in a circuit. (16.95%)	1) Potential difference creates the current. (1.00) 2) Electrons flow by vibration and energy is transported in a circuit. (1.00)
	To observe a potential difference between two points, charges on the two points should be opposite to each other. (13.38%)	1) Sign of charges have no importance (0.50) 2) Potentials of two different points have to be different from each other. (1.00)
	To change potential difference in a circuit, current should be changed. (9.85%)	1) Potential difference in a circuit is created by the power supply and changes by only changing it not the current. (1.00)
	Potential difference is a vector quantity. (13.73%)	1) Potential difference is a scalar quantity; therefore, it has no direction and application point. (1.00)
	When a battery runs out, potential difference becomes 0 (zero). (5.96%)	1) If a battery is not connected to a closed circuit and a voltmeter is connected between its terminals, we can detect that there is still a potential difference. (1.00)
	Potential difference is the power of a battery. (12.92%)	1) While the unit of power is watt, the unit of potential difference is volt. (1.00) 2) Potential difference is the difference between the potentials of two different points; whereas power is the work done per unit of time. (0.50)
	There is no difference between potential difference and potential energy. (6.62%)	1) Potential difference is the difference between the potentials of two different points, it is not energy. (0.50) 2) The unit of potential difference is volt, whereas the unit of potential energy is joule. (1.00)

As can be seen from Table 4.19 when examined closely, four of the eight teacher-introduced misconceptions seem to be most-recognized student misconception related to electric current, gathering almost 62% of teacher responses. These are the misconceptions that are discussed mostly in the literature: ‘Potential difference is the potential of a point,’ ‘potential difference flow in a circuit,’ ‘to observe a potential difference between two points, charges on the two points should be opposite to each other,’ and ‘potential difference is a vector quantity.’ Teacher introduced misconceptions about electrostatic force is given in Table 4.20.

Table 4.20 Teacher Introduced Misconceptions about Electrostatic Force

Electrostatic Force	There is not an electrostatic force. (18.73%)	1) There is electrostatic force and calculated by Coulomb’s Law. (0.50) 2) It is the force that provides ebonite stick, rubbed on a piece of woolen cloth (or glass rod, rubbed on a piece of silk or comb, rubbed on hair), to pull paper pieces. (1.00)
	An object whose amount of static charge is more than the other, exert a stronger electrostatic force on the other object. (30.56%)	1) Electrostatic force observed between objects influencing each other is equal in magnitude but opposite in direction. (0.50) 2) According to Coulomb’s Law, magnitude of electrostatic force exerting on two objects is directly proportional with objects’ amount of charges and equals to each other. (0.50) 3) Action and reaction forces have equal magnitudes. (1.00)
	There is no interaction between charged and neutral objects. (25.98%)	1) A charged object firstly charges a neutral object by induction, and then pulls the neutral object to itself. (0.50) 2) Ebonite stick, rubbed on a piece of woolen cloth, pulls paper pieces. Neutrality of paper pieces has no effect on this situation. (1.00)
	Electric field and electrical force have the same direction. (12.19%)	1) Electrical force is exerted on positive charges in the same direction of electric field, but is exerted on negative charges in the opposite direction of electric field. (1.00) 2) The direction of electric field is always from positive to negative, whereas direction of electrical force depends on both of the direction of electric field and type of charge. (1.00)
	There is no difference between the electrical force and electric field. (12.54%)	1) If there is a charge in electric field, electrical force is exerted on that charge. (0.50) 2) Both of them are vector quantities. However, if the type of charge in the electric field is negative, electrical force exerted on the charge is in the opposite direction of electric field. (1.00)

According to Table 4.20 when examined closely, three of the five teacher-introduced misconceptions seem to be most-recognized student misconception related to electric current, gathering almost 73% of teacher responses. These are the misconceptions that are discussed mostly in the literature: ‘An object whose amount of static charge is more than the other, exert a stronger electrostatic force on the other object,’ ‘there is no interaction between charged and neutral objects,’ and ‘there is not an electrostatic force.’

The correct responses in all the KSUE items except for the last item and the misconceptions with refutation statements in the last item provided by the participants were checked against relevancy of the responses by the co-supervisor, the researcher and two PhD candidates. In addition, scores for each correct response and refutation statements also were determined by the same group of people. Therefore, we did not need to check and compare students’ learning difficulties and misconceptions in electricity provided by the participants with the existing literature. Table 4.21 shows the frequency of scores obtained for Items 1, 2, 3, 6, 7, 8, 9, and 10.

Table 4.21 Frequency of Scores in Items 1, 2, 3, 6, 7, 8, 9, and 10

Scores	Item 1	Item 2	Item 3	Item 6	Item 7	Item 8	Item 9	Item 10
0.00	14	7	16	4	6	10	9	12
0.25	30	32	-*	28	23	-*	-*	24
0.50	55	24	70	25	32	36	29	-*
0.75	-*	21	-*	33	28	44	55	50
1.00	-*	16	22	13	11	-*	-*	15
1.25	-*	11	-*	10	9	17	13	14
1.50	19	5	12	6	6	15	17	-*
1.75	5	5	-*	3	5	-*	-*	8
2.00	1	3	4	2	4	2	1	1

* It is not possible to obtain this score due to the distributions of scores according to the correct responses.

Table 4.21 shows that there are some teachers whose responses were scored as 0. There was only one participant, whose responses were scored as 2 points, in items 1, 9 and 10.

In the last item of PECKI, we observed 10, 8 and 5 different teacher introduced misconceptions regarding current, potential difference and electrostatic force, respectively. Maximum available score for that item was 6. Distribution of scores in this item was represented in Table 4.22. There was only one participant who wrote one misconception for each of the concepts and refuted them convincingly; therefore, his/her response was scored as 6 points.

Table 4.22 Distribution of Scores in Last Item of PECKI

Score	Frequency
0.00	10
1.00	17
1.50	12
2.00	17
2.50	15
3.00	22
3.50	10
4.00	6
4.50	6
5.00	4
5.50	4
6.00	1

Results of KSUE show that teachers' scores in this dimension of PCK have a normal distribution. This means that there are a number of teachers whose knowledge of student understanding (that is, learning difficulties and misconceptions) seems limited. When examined closely, it can be detected that, in each item of this dimension, there are some teachers whose responses were scored as 0. There were two main reasons of why a participant's response was scored as

0. First one was non-responded items which were scored as 0. Second one was the irrelevancy of participants' answers to the items. In most of 0-point scored items, participants gave a response; however, their responses did not include a student's pre-instructional thinking or a misconception.

4.2.2 Survey Results of Teachers' Knowledge of Instructional Strategies

The names and definitions of the codes utilized in the study were presented independently from the topic of electricity in the study. Regarding the study, this may create a perception as if it is opposite to the structure of PCK which is already a topic-specific knowledge. The items in this dimension of the instrument completely focused on some concepts of electricity. Therefore, results of the study in this dimension of PCK should not be accepted as that they are measuring high school physics teachers' pedagogical knowledge instead of their PCK.

There were only 4 open-ended items, 11^{th}, 12^{th}, 13^{th} and 14^{th} items, constructed for the assessment of physics teachers' KIS as can be seen in Table 3.3. All the items in this component of PCK presented participants with a learning difficulty or a misconception students possess; and then asked for how they teach the subject in that situation. The questions were structured such that teachers were requested two different responses. Firstly, each item asked how the participants would teach the subject to a new group of students taking into account the student learning difficulty or misconception presented in each item. Secondly each item also asked the participants about how they would teach if they needed to repeat the subject in the presence of the student learning difficulty or misconception. In this way, we wanted to observe at least two different instructional strategies in responses to these items. Additional points were awarded depending on whether teachers provided a different strategy for the second part of the question.

During our qualitative analysis we encountered a critical problem. This was the number of data sources being included in analysis. We only utilized participants' answers given to four open-ended items in analysis. Our main aim was the assessment of a teacher's PCK with a single implementation. This would increase the repetition of our study by other researchers. However, it was, in most cases, very difficult to grasp whether a teacher would make all the requirements of an instructional strategy in his/her classroom. Because, participants generally preferred to write their answers in a few sentences. This deficiency in our data forced us during matching the answers with the codes. In these situations, we matched an answer with the closest code to that answer. In other words, if a teacher's answer was briefly including some critical aspects of an instructional strategy we admitted that this teacher was implementing that instructional strategy in his/her classroom. For example, if a teacher stated that I provide my students to make an experiment about power of lamps and give enough time to them for thinking on and analyzing the data to empower their meaningful learning, we then matched this answer with inquiry strategies from our codes.

In following sub-sections you can see firstly the qualitative analysis results of these 4 items were presented, followed by a summary of the results of KIS. In analysis of each item, we gave some numeric information including the number of observations with their matched codes and frequency of observed strategies. Then, we presented some teacher responses from our implementation. In the summary of this title, we also presented whole distribution of participated teachers' preferences regarding instructional strategies.

4.2.2.1 Analysis of 11th Item

There were 124 teachers participated in the study. 14 of the participants gave no response or not a valid response matching with our codes to this item meaning that whose responses could not be categorized into an instructional strategy. The remaining 110 teachers provided at least one strategy, which we considered as a sign of taking students' difficulty in selecting a teaching strategy. We observed at least one instructional strategy in a responded and valid paper. The maximum number of the instructional strategies that we observed in a paper was three. We observed 194 instructional strategies in total distributed to our codes which included 5 different types of instructional strategies. Table 4.23

presents the distribution of observed instructional strategies to our codes with their percentages.

Table 4.23 Distribution of Observed Instructional Strategies for Item 11

Code	Number of observation	Percentage
Direct instruction	158	81.5%
Enhanced context strategies	18	9.2%
Cooperative learning strategies	9	4.6%
Inquiry strategies	7	3.6%
Conceptual change strategies	2	1%

Teacher responses got extra point in scoring if there was a change in instructional strategy preferences of teachers for repetition of the subjects. We observed only 21 responses in which teachers changed their instructional strategy preferences. Table 4.24 shows the distribution of scores for Item 11.

Table 4.24 Distribution of Scores for Item 11

Number of Different Strategies	Score	Frequency
0	0	14
1	3.25	89
2	6.50	21

Results showed that participant teachers are mostly implementing direct instruction in their classrooms. Second most frequently stated strategy was enhanced context strategies. However, there is a big difference in number of implementation of these two instructional strategies. Furthermore, all the teachers who provided instructional strategies different from direct instruction have stated that they experienced the student learning difficulty/misconception presented in this item.

To illustrate the coding of teacher responses we presented answers of three teachers selected randomly. Scanned images of the papers were given in Appendix I. Teacher A wrote that she firstly would provide them to realize the differences by giving examples from their environments and asking them how the lamps in different rooms in their homes were lighting. This part of her answer giving some clues to match with enhanced context strategies, since she tried to relate learning to the students' environment. She, then, stated with that she would want her students to compare the brightness of lamps by increasing the number of the lamps and by making students to try different types of circuits in the classroom. In this part of her answer, she seemed to provide her students making an experiment in classroom and getting their own results. For this part of her answer, we admit that she was implementing inquiry strategy in the classroom. For the repetition part, she stated that she would reinforce the subject with new types of questions. This part could not be matched with instructional strategies included in the study and scored as 0 point. As a result we observed two different instructional strategies which were enhanced context strategies and inquiry strategies, in her answer to this item and scored her paper as 6.5 point.

In another example, Teacher B stated that in laboratory he would divide his students into groups of 4 or 5 students. Then, he would ask them to set up a real circuit with the laboratory equipment. In the next step, he would want them to represent their circuits in physical symbols meaning perhaps to ask students to draw circuit diagram. Then he would set up an example of circuit, and compare the values they calculated with the values they found as a result of the experiment by using formulas. This part of teacher B's answer was matched with cooperative learning strategies. For the second part, he stated that he would do the same operations stated in the first part. Therefore, his response was scored as 3.25 in this item.

In final example, Teacher C stated that resistances placed between the same letters are connected in parallel to each other. If other resistances appear in the figures we can put in order them by changing the letters. She also made different type of drawings on her paper to show the letter use. Her response was matched with direct instruction, since she most probably shows this letter use method on the blackboard and provides information about its usage explicitly. For the repetition part, she made only same types of drawings on the paper, so we observed only direct instruction in her response was scored as 3.25 in this item.

We observed letter use method stated by Teacher C in 46 times among all the observations. This method does not seem to contribute students' conceptual understanding but helps students to solve the problems including complex connections of resistances in a circuit.

4.2.2.2 Analysis of 12th Item

There were 124 teachers participated in the study. 17 of the participants gave no response or not a valid response matching with our codes to this item meaning that whose responses could not be categorized into an instructional strategy. The remaining 107 teachers provided at least one strategy, which we considered as sign of taking students' difficulty in selecting a teaching strategy. We observed at least one instructional strategy in a responded and valid paper. The maximum number of the instructional strategies that we observed in a paper was two. We observed 132 instructional strategies in total distributed to our codes which included 5 different types of instructional strategies. Table 4.25 presents the distribution of observed instructional strategies to our codes with their percentages.

Table 4.25 Distribution of Observed Instructional Strategies for Item 12

Code	Number of observation	Percentage
Direct instruction	112	84.8%
Inquiry strategies	9	6.8%
Cooperative learning strategies	7	5.3%
Enhanced context strategies	3	2.3%
Conceptual change strategies	1	0.8%

There were only 14 teachers who changed their instructional strategy preferences for repetition of the subject. Table 4.26 shows the distribution of scores for item 12.

Table 4.26 Distribution of Scores for Item 12

Number of Different Strategies	Score	Frequency
0	0	17
1	3.25	93
2	6.50	14

Results showed that participant teachers are mostly implementing direct instruction in their classrooms. Second most frequently stated strategy was inquiry strategies. However, there is a big difference in number of implementation of these two instructional strategies. Furthermore, all the teachers who provided instructional strategies different from direct instruction have stated that they experienced the student learning difficulty/misconception represented in this item.

To illustrate the coding of teacher responses we presented answers of two teachers selected randomly. Scanned image of the paper was given in Appendix I Teacher D stated in his paper that he firstly would explain the way and amplitude of the current created by the first battery, then he would explain the way and amplitude of the current created by the second battery. Finally, he would explain that currents had to be summed if they were on the same direction or subtracted if they were on the opposite directions. This part of his answer was matched with direct instruction from our codes, since only the teacher was delivering information explicitly.

Teacher D also gave answer for the repetition part of the item. He wrote in this part that he would set up the circuit with voltmeter, ammeter, resistance and power supply. Then, he would explain by making clarifications on the circuit and schema or he would explain the movement of current by showing simulations on the computer. In this part of his answer the teacher seemed to benefit from lab equipment, but he was still at the center of the learning process and making clarifications explicitly. Therefore, this part of Teacher D' answer was also matched with direct instruction. As a result, we observed two instructional strategies in Teacher D's response; however, both of these strategies were direct instruction. Therefore, we scored his response as 3.25 point in this item.

In another example, Teacher E stated that he would give a lecture by drawing the currents coming from the different batteries with colorful pens and attaining numerical values to them, if possible. His response in this part was matched with direct instruction. In the second part he stated that he would give some similar examples. Then, he would divide students into groups and give them similar problems. Finally, he would offer students to come to next lesson be prepared and make discussions. This part of his giving some clues about direct instruction; however, remaining part could not be matched with any instructional since the type and result of student discussions are not definite. Therefore, his response included two following direct instruction and scored as 3.25.

4.2.2.3 Analysis of 13th Item

There were 124 teachers participated in the study. 13 of the participants gave no response or not a valid response matching with our codes to this item meaning that whose responses could not be categorized into an instructional strategy. The remaining 111 teachers provided at least one strategy, which we considered as sign of taking students' difficulty in selecting a teaching strategy. We observed at least one instructional strategy in a responded and valid paper. The maximum number of the instructional strategies that we observed in a paper was two. We observed 178 instructional strategies in total distributed to our codes which included 5 different types of instructional strategies. Table 4.27 presents the distribution of observed instructional strategies to our codes with their percentages.

Table 4.27 Distribution of Observed Instructional Strategies for Item 13

Code	Number of observation	Percentage
Direct instruction	135	75.8%
Enhanced context strategies	15	8.4%
Inquiry strategies	13	7.3%
Cooperative learning strategies	9	5.1%
Conceptual change strategies	6	3.4%

Teacher responses got extra point in scoring if there was a change instructional strategy preference of teachers for repetition of the subjects. There were only 24 teachers who changed their instructional strategy preferences for repetition of the subject. Table 4.28 shows the distribution of scores for Item 13.

Table 4.28 Distribution of Scores for Item 13

Number of Different Strategies	Score	Frequency
0	0	13
1	3.25	87
2	6.50	24

Results showed that participant teachers are mostly implementing direct instruction in their classrooms. Second most frequently stated strategy was enhanced context strategies. However, there is a big difference in number of implementation of these two instructional strategies. Furthermore, all the teachers (except for 1 participant) who provided instructional strategies different from direct instruction have stated that they experienced the student learning difficulty/misconception represented in this item.

To illustrate the coding of teacher responses we presented answers of two participants selected randomly. Scanned images of the papers were given in Appendix I. Teacher F wrote in her answer that she would firstly determine the misconceptions of previous students, and then she would deliver a refutation text based on the students' misconceptions. Then, she would repeat the subject with examples to support the students' learning. In this situation students seemed not to understand how the potential difference distributed in parallel and series circuits, and they seem not to grasp the relation between current and brightness. This part of teacher F's answer was matched with conceptual change strategies. In the second part of her answer, she stated that she would do the same operations stated in the first part, and if she needed another strategy, she requested support from her colleagues. This part could not be matched with instructional strategies included in the study and scored as 0 point. As a result we observed only one instructional strategy which was conceptual change strategies, in her answer to this item and scored her paper as 3.25 point.

Teacher G stated that brightness is related with power. For the identical lamps, brightness equals to $\frac{V2}{R}$ or i^2R. It was explained that the brightest lamp has the highest voltage. Then, sequencing was realized on the figure by via finding the voltages. It was shown that brightness was also sequenced in accordance to the voltages. Additionally, he stated that this figure could be shown by setting up the circuit with lab equipment. His answer in this part was matched with direct instruction. In the repetition part, he stated that he would make examples by attaining numbers on the figure. It was clarified that brightness was sequenced in accordance to the voltage. Then, students could be provided to grasp the relationship between brightness and power by calculating the power of each lamp. This part of his response was also matched with direct instruction. Therefore, his response was scored with 3.25 since it only included two following direct instruction.

4.2.2.4 Analysis of 14th Item

There were 124 teachers participated in the study. 18 of the participants gave no response or not a valid response matching with our codes to this item meaning that whose responses could not be categorized into an instructional strategy. The remaining 106 teachers provided at least one strategy, which we considered as sign of taking students' difficulty in selecting a teaching strategy. We observed at least one instructional strategy in a responded and valid paper. The maximum number of the instructional strategies that we observed in a paper was two. We observed 125 instructional strategies in total distributed to our codes which included 3 different types of instructional strategies. Table 4.29 presents the distribution of observed instructional strategies to our codes with their percentages.

Table 4.29 Distribution of Observed Instructional Strategies for Item 14

Code	Number of observation	Percentage
Direct instruction	102	81.6%
Conceptual change strategies	18	14.4%
Enhanced context strategies	5	4%

There were only 11 teachers who changed their instructional strategy preferences for repetition of the subject. Table 4.30 shows the distribution of scores for item 19.

Table 4.30 Distribution of Scores for Item 14

Number of Different Strategies	Score	Frequency
0	0	18
1	3.25	95
2	6.50	11

We could not detect any participant writing that he/she would implement inquiry strategies or cooperative learning strategies in the classroom for overcoming student learning difficulty presented in the item. There was a student misconception/conceptual confusion to be solved by the teacher in this item. This situation seemed to increase the usability of conceptual change strategies with regard to previous items. However, direct instruction was still the mostly preferred instructional strategy that teachers intended to adapt in their classrooms. Furthermore, all the teachers who provided instructional strategies different from direct instruction have stated that they experienced the student learning difficulty/misconception represented in this item.

To illustrate the coding of teacher responses we presented answers of three participants selected randomly. Scanned images of the papers were given in Appendix I. Teacher H stated that he tries to clarify the concepts with some drawings including glasses and water. In his drawings, potential energy of waters or points which were placed at different altitudes was used analogs for potential. In these drawings, he seemed to relate students' previous knowledge to the new concepts; therefore, his response was matched with enhanced context strategies and scored with 3.25 point since he did not give an answer for the repetition part.

Teacher I stated that he would present the similar concepts from mechanics in both situations. He would explain potential as the altitude in accordance to the Earth and potential difference as the difference of two separate points' altitudes in accordance to the Earth. His response also included a simple drawing representing this relation between concepts. This response was interestingly same with teacher I's response. Therefore, this response was also matched with enhanced context strategies as scored as 3.25.

Teacher J stated that he firstly would explain the concept of potential by beginning from potential of a point. Then, he would start to talk about potential difference and provide to confirm the concepts. This part of his answer was matched with direct instruction since he seemed to explain the concepts explicitly. For the second part, he stated that he would try to confirm the difference between concepts after reminding the concepts of potential of a point and potential difference to prevent students from conceptual confusion. In this part, he also seemed to realize direct instruction in the classroom. Therefore, his response included two instructional strategies, but both of them was direct instruction and scored as 3.25.

Regarding our observations in this item, it was remarkable that there were only five teachers who intended to utilize enhanced context strategies in the same way in their classrooms. All these teachers intended to select similar concepts from mechanics as analogs for explanation or introduction of the new concepts from electricity.

4.2.2.5 Summary of Teachers' Knowledge of Instructional Strategies

We presented the details regarding teachers' responses item by item, in previous sub-sections. In this sub-section of the results, we presented percentages of instructional strategies provided by the participants and overall summary of the KIS results. To show the distribution, including which type of instructional strategies mostly preferred by the participant teachers, we prepared Table 4.31 that also represents the percentages of instructional strategies.

Table 4.31 Percentages of Instructional Strategies

Code	Total	Percentage
Direct instruction	507	80.6%
Enhanced context str.	41	6.5%
Inquiry strategies	29	4.6%
Conceptual change str.	27	4.3%
Cooperative learning str.	25	4%

Table 4.31 clearly shows that the participant teachers mostly preferred direct instruction in their teaching processes with 80.6% in all observed instructional strategies followed by enhanced context, inquiry, conceptual change and cooperative learning strategies. This does not necessarily mean that teachers are actually using these strategies in their instructional practices. It is merely a projection of their knowledge of strategies.

Furthermore, the participants who intended to implement instructional strategies different from direct instruction were the ones who previously experienced the student learning difficulties or misconceptions presented in the items. There was only one participant which contradicts our observation who, even though did not experience student learning difficulty or misconception, wrote down a strategy other than direct instruction. Based on these results, it would not be illogical to conclude that if a teacher experienced a particular difficulty or misconception, s/he is likely to utilize strategies other than direct instruction.

Another remarkable result of the analysis was instructional strategy sequence in teachers' preferences. Most of the participants intended to implement same instructional strategy both for the first time teaching and for the repetition of the subject represented in items. This intention was also observed between items. I mean that if a teacher intended to implement direct instruction for the 11^{th} item, this was also observed in other items of the same participant teacher.

4.3 Summary of the Results

In answering the first research problem of the study we did not only tried to develop an instrument but also but also realized validation processes via five additional research hypotheses. We eliminated Items 4 and 5 based on exploratory and confirmatory factor analysis together with physics educators' suggestions among all other PECKI items because of issues about these items' significance of predictions and factor loadings. Therefore, in confirmatory structural modeling PECKI included 13 items; 9 for KSUE and 4 for KIS. In confirmatory SEM we focused on two different models which were proposed models. Based on the results, we selected the proposed model I which was more appropriate to explain the relations among the variable of the study with better fit values. And also, proposed model I explained 67% of the variance regarding PCK which was more than the proposed model II (61% of the variance of PCK). Confirmatory SEM analysis showed that, teachers' PSE level, in-service training attendance and specific experiences were the significant predictors of their PCK. In addition to them, teachers' job satisfaction levels and years of teaching experience were not found as significant predictors of their PCK. Therefore, this study produced content- and construct-related evidence for the validation. However, results of the study did not meet all the expectations that we had at the beginning of the study regarding construct validity of the instrument.

The study included two more research problems both of which were related to the assessment of high school physics teachers' knowledge about students' pre-instructional thinking and misconceptions in electricity and teachers' knowledge of instructional strategies related to the teaching of electricity. Results of this study showed that high school physics teachers provided some information regarding their students' pre-instructional thinking and misconceptions; however, distribution of teachers' scores in this this dimension of the instrument presented a normal distribution. In other words, there were many teachers whose KSUE levels are below the average. In addition, physics teachers mostly preferred to implement direct instruction as the instructional strategy in their teaching courses to overcome students' learning difficulties and misconceptions in electricity. Furthermore, being experienced on the student learning difficulties and misconceptions seemed effective on their selection of instructional strategies. The participants who intended to utilize instructional strategies different from direct instruction were the ones who previously experienced the student learning difficulties or misconceptions presented in the items.

CHAPTER 5

DISCUSSIONS, CONCLUSIONS AND IMPLICATIONS

This chapter of the study presents discussions of the results, conclusions, implications, and finally, recommendations for future research studies.

5.1 Discussions of the Results

PECKI included two dimensions, namely KSUE and KIS, for measurement of teachers' PCK related to teaching of electricity. In science and technology education, other researchers also included these dimensions in their studies regarding PCK assessment (Halim & Meerah, 2002; Lange et al., 2009; Rohaan et al., 2009). In this regard, our PCK components are in line with what the other researchers expected from an instrument developed for teachers' PCK.

In validation of the instrument, we utilized exploratory and confirmatory factor analyses followed by the confirmatory SEM analysis. Based on the PCK literature, we proposed two different models to utilize in confirmatory SEM analysis for establishing construct related evidence for validity. According to the proposed model I of the study, the coefficient showing PSE's direct effect on JS was 0.95. That is, teachers' PSE level has a positive and high level of prediction on their JS level. Similar results were also obtained in the literature (Caprara et al., 2003; Viel-Ruma et al., 2010).

Our results imply that JS is not a significant predictor of PCK. The literature regarding JS provides evidence that employees' JS level can positively predict their professional knowledge levels (Van der Heijden & Brinkman, 2001). Even though there are, to the best of our knowledge, no research studies investigating the relation between teachers' PCK and JS level, above evidence directed us to utilize the JS level of physics teachers' as a predictor of their PCK. In a survey study, Azar and Henden (2003) identified JS level of primary school teachers who were appointed out of their profession or subject area. They found that those primary school teachers had low JS scores which were most probably a result of deficiency in those teachers' professional knowledge compared to those of whom trained specifically to become primary school teachers. In our study, we found a small effect of teachers' JS level on their PCK but this was stemmed mostly from PSE. In proposed model II, JS seemed to have a significant effect on PCK. However, in that model, we did not include PSE's indirect effect where JS was a mediator in the relation between PSE and PCK. In the proposed model I, when this effect was added, JS influence on PCK has become negligible. This may because of the inadequacy in number of items in JS dimension of our instrument.

According to the results, teachers' PSE level has the highest direct effect on their PCK. In the literature, there are several studies revealing the relationship among teachers' self-efficacy beliefs and their PCK (Khourey-Bowers & Simonis, 2004; Posnanski ,2002; Swackhamer et al., 2009). Additionally, some researchers stated that teachers' beliefs – including PSE – affect their PCK development (Gess-Newsome, 1999a; Magnusson et al., 1999; Tobin & McRobbie, 1999; van Driel et al., 2001). Based on such research studies, we investigated in our model the existence of a relation between teachers' PCK and PSE level. Because of the limitations of AMOS we set out PSE as a predictor of PCK in our model. However, if it were possible, it would have been a more logical analysis when PCK and PSE are set in the model as correlating variables. As a result of our analysis, we found that teachers' PSE level has a positive and direct effect on their PCK. That mean, the more PCK teachers have, the more they will believe in themselves to be effective in teaching which is what one would logically expect: If a teacher's pedagogical 'toolbox' is quite rich, he/she would feel that he/she would be successful in his/her instructional practice.

As part of the validation process, we investigated the relationship between teachers' years of teaching experience and PCK, which was originally thought to have existed. However, as both later research studies pointed out, we did not find a significant effect of year of teaching experience on teachers' PCK. However, specific experiences defined as whether the participant teachers experienced the student learning difficulties or misconceptions, represented in PECKI items, in their classroom context have a significant effect according to the proposed model I. Even though earlier research on PCK implied the effect of teachers' years of teaching experience on teachers' PCK (Crawford, 1999; Holt-Reynolds, 2000; Morine-Dershimer & Kent, 1999), recent research studies stressed the importance of teachers' specific experiences on their PCK (Abd-El-Khalick, 2006; Park & Oliver, 2007). It may be expected that a teacher's specific experiences and year of teaching experience should have a positive relation between themselves and have the same effect on teachers' PCK. In this study, we assumed that teachers' specific experiences create chances for them to be reflective in/on their teaching courses. Our expectations regarding teachers' specific experiences were supported; however, we found an opposite result related to teachers' years of teaching experience. This opposite result can rightfully be attributed to the possibility of participants' intention for implementing mostly direct instruction in their classrooms. These results show that mere number of teaching experience, without a conscious reflection on one's actions, has no effect on one's PCK. The research regarding PCK in recent years is already moving it focus more towards this view: teachers' specific experiences rather than their years of teaching experience is influential on the development of PCK.

Although the attendance of in-service training seminars regarding physics teaching programs has a potential to positively predict PCK (Gess-Newsome, 1999b, Magnusson et al., 1999, Nilsson, 2008), our study surprisingly found an opposite result; that is, teachers who attended to more in-service training seminars had lower PCK scores compared to those who attended less seminars. This might be due to the content of in-service training seminars the participants attended to and also due to reluctance of the participants from the in-service training seminars to adequately filling the PECKI forms. There are two possible explanations for the discrepancy between our expectations and findings. First, to the best of our knowledge, none of the in-service training seminars that the participants of this study have attended focused specifically on the issues related to the two components of the PCK this study has focused on. In this regard, it is not reasonable to expect improvement in teachers' PCK in KSU and KIS. However, the transformative model of PCK suggests that an improvement of one component of PCK results in the improvement of other components as well. In this regard, one, albeit weak, possibility is that regardless of the content of seminars, teachers might have developed PCK related to the teaching of electricity. Yet, no evidence can be set forth to support this assumption. Second explanation is related to the invaluable opportunity for researchers to study teachers in in-service training seminars. The attendants often have been asked to participate in studies in which they fill several questionnaires or are interviewed. Therefore, the more training programs they attend, the more instruments they fill, which results in reluctance of teachers towards participating in subsequent research studies. Before collecting data from these participants, we did not consider teachers' reluctance as a threat to internal validity; hence, no precautions were taken for this threat. Of the two explanations, in light of the above discussions, the second one seems more plausible.

Second and third research problems of the study were survey problems about what teachers know regarding their students' learning difficulties and misconceptions and what type of instructional strategies they implement to overcome these learning difficulties and misconceptions in teaching of electricity. Results showed that teachers' knowledge about their students' learning difficulties and misconceptions presented a normal distribution. There were many participants whose scores were below the average in this dimension of PCK. In addition to this, teachers mostly preferred to implement direct instruction in their classrooms. Deficiency in teachers' knowledge regarding their students' learning difficulties and misconceptions might divert them to implement direct instruction in their teaching courses. Because, in direct instruction, where no differentiation based on student differences/difficulties is needed. Nor alternative methods to overcome such difficulties or misconceptions are necessary when one is ignorant of these issues. Additionally, the teachers whose knowledge is deficient regarding students' learning difficulties and misconceptions almost cannot be effective teachers in their classrooms.

5.2 Conclusions

One of the main purposes of this study was to provide validity of interpretations on teachers' responses. We established validity of PECKI results in two ways. Firstly, we collected experts' opinion regarding our items' content validity before our two different implementations. Based on their suggestions some of the PECKI items were revised. Therefore, we can conclude that we have established content-related validity of PECKI results.

Secondly, we provided evidence for construct validity of PECKI items in two steps. In the first step, we conducted an exploratory and confirmatory factor analyses on all the 15 PECKI items, in two factors: KSUE and KIS. Exploratory factor analysis produced three factors whose content was different from our original intentions. However, we decided to include all the items of the instrument based on physics educators' views in CFA. Based on the CFA results, we had to omit two items from PECKI because of low factor loadings and problems regarding significance of prediction. Actually, we conducted CFA to decide which items could be incorporated into the second step of analysis, confirmatory SEM for construct-related validity of PECKI scores. In the second step, we conducted a confirmatory SEM analysis on the remaining 13 items with other variables of the study. We had two different proposed models. Based on the SEM results, we eliminated the proposed model II because of poorer fit values and variance ratio explained by this model. According to our proposed model I, physics teachers' PSE level has the highest positive prediction on their PCK related to teaching of electricity. Teachers' specific experiences are also positively predicting their PCK. Additionally, teachers' JS level and years of teaching experience have no significant effect on PCK. Contrary to the literature-based expectations, attendance to in-service training seminars regarding physics teaching programs had a negative effect on teachers' PCK, most probably because of irrelevancy of content of these seminars to the PCK related to the teaching of electricity and reluctance of the participants attending the in-service training seminar. As a result, we can conclude that some of the CFA and confirmatory SEM analysis provided construct-related evidence for PECKI items, while others did not fulfill our expectations, which we believe need further investigation.

In addition to the validity estimation, we calculated reliability of PECKI results in two ways. First one was the inter-rater reliability of teachers' scores in 11 items constructed for assessment of teachers' KSUE. Pearson product-moment correlation (r) was found as 0.86 in this step. The second one was the inter-rater reliability in coding of 4 items constructed for assessment of teachers' KIS. Percent agreement was found as 78% in this step. As a result, we can conclude that teachers' scores have moderately high reliability.

Regarding the survey results we found in KSUE and KIS dimensions, we can firstly conclude that teachers' KSUE scores have a normal distribution that is there are many teachers whose KSUE scores were below average. In addition to this, qualitative analysis of KIS data showed that teachers' mostly preferred to implement direct instruction in their classrooms as a first choice of instructional strategy for overcoming their students' learning difficulties and misconceptions. Furthermore, the participants who intended to implement instructional strategies different from direct instruction were the ones who previously experienced the student learning difficulties or misconceptions presented in the items.

5.3 Implications

Suggestions about implications of the results can be made based on the following results: Firstly, this study showed that teachers' scores in KSUE had a normal distribution. Additionally, being experienced on a specific student learning difficulty or misconception positively affected teachers' PCK. On the other hand, teachers' years of teaching experience do not have an effect on their PCK. In this regard, we offer that pre-service teachers should be incorporated into teaching assignment courses in real classroom environments in which they can experience examples of student learning difficulties and misconceptions.

Another cluster of suggestions can be made regarding usage of instrument developed in our study. Turkish teacher candidates have to join public personnel selection examination to be appointed in public schools. This exam has two different parts: general ability and culture, and educational sciences. This exam is not changing in accordance to the subject areas of teacher candidates. If these types of instruments are developed for other subjects, titles and dimensions of PCK, it will be more appropriate to utilize these instruments in selection of teachers. Next, these types of instruments can be utilized in assessment of teacher qualifications. Turkey Ministry of National Education has completed the determination period of teacher qualifications for all subjects.

Finally, our study showed that high school physics teachers mostly prefer to implement direct instruction in their teaching courses to overcome student difficulty or misconceptions. In addition to this, teachers' specific experiences have a positive effect on their preferences in terms of their selection of other strategies. Based on these findings, we offer that the professional development programs designed for in-service teachers and the courses designed for pre-service teachers should inform them regarding different type of instructional strategies and how to implement these strategies.

5.4 Recommendations for Future Research Studies

Our recommendations for future research studies were presented as below:

1) PECKI was administered to 124 high school physics teachers in this study. The number of participants should be increased in future studies.
2) The second objective of the instrument consisted of only one item whose total maximum score was 6 while it was 2 for the other items in first dimension of PCK. For the following researchers we suggest to increase the number of items for this objective.

3) PECKI items focused on electrostatic, electric fields, circuits, electric potential, and electric energy and power as the physics concepts related to electricity. However, there are still other concepts left out in this study. In this regard, we firstly suggest that other concepts should also be focused in measurement of PCK. Secondly, other domains in physics such as waves, kinematics, etc… should also be investigated. Finally, we suggest that instruments developed for the measurement of teachers' PCK should specify on one concept rather than many concepts. In so doing, interpretations will be much easier for the researchers. In this way, measurement studies can give a more comprehensive picture of physics teachers' PCK.
4) We developed a survey instrument including open-ended items in the study. But, however difficult it may be, we suggest developing a test that consists solely of selection type items, particularly multiple-choice items. This type of items may contribute positively to the reliability estimation of scores, reaching to high number of participants in these studies and completing the evaluation procedures in a short time duration.
5) Caution must be taken when studying with participants who are attending in-service training seminars, as they seem to be reluctant to participate in research studies.

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APPENDIX A

INSTRUMENT OF FIRST IMPLEMENTATION

ELEKTRİK KONUSUNA YÖNELİK PEDAGOJİK ALAN BİLGİSİNİ ÖLÇME TESTİ GELİŞTİRME ÇALIŞMALARI

Cinsiyetiniz: ☐ Bay ☐ Bayan

Öğretmenlik Deneyiminiz: _____ yıl

Şu Anda Görev Yaptığınız

Okul Türü: ______________________

İl: ______________________

Mezun Olduğunuz Bölüm: ☐ Fizik
☐ Fizik Öğretmenliği
☐ Diğer (Bölüm adını belirtiniz …………………….)

Dersine Girdiğiniz Sınıflar : ☐ 9. Sınıf ☐ 10. Sınıf ☐ 11. Sınıf ☐ 12. Sınıf

Daha önce "Fizik Dersi Öğretim Programları" ile ilgili hizmet içi eğitim kurslarına katıldınız mı? ☐ EVET ☐ HAYIR

Cevabınız "Evet" ise Katılmış Olduğunuz Hizmet İçi Eğitim Kurslarının;

	İlk Katıldığım Kursun	**İkinci Katıldığım Kursun**	**Üçüncü Katıldığım Kursun**	**Dördüncü Katıldığım Kursun**
Süresi				
Yeri				

Lütfen teste başlamadan önce yukarıdaki kutucuğu doldurunuz.

Değerli öğretmenim;

Elinizdeki ankete vereceğiniz cevaplar doğrultusunda fizik öğretmenlerimizin elektrik konusuna yönelik pedagojik alan bilgilerini ölçmek amacında olan bir test oluşturulacaktır. Anketten alacağımız verileri **kesinlikle sizi değerlendirmek amacı ile kullanmayacağız**. Vereceğiniz cevaplar testin geliştirilmesi sürecinde önemli katkılarda bulunacaktır. Bu süreçte size ait hiçbir **kişisel bilgiye ihtiyaç duyulmamaktadır.** Sorulara anlaşılır şekilde kısaca cevap vermeniz yeterlidir. Lütfen her soruya cevap vermeye gayret ediniz.

TEŞEKKÜR EDERİM

Eralp Bahçivan

Doktora Öğrencisi

OFMAE-Orta Doğu Teknik Üniversitesi

1) a) Elektrik konusu kapsamında öğrencilerinizde sıklıkla karşılaştığınız kavram yanılgılarına iki örnek veriniz?

b) Sizce öğrencilerinizin bu kavram yanılgılarına sahip olmalarının sebepleri nelerdir?

c) Bu kavram yanılgılarından kurtulma konusunda onlara nasıl yardımcı oluyorsunuz? Kısaca öğretim dizaynınızın içeriğinden ve aşamalarından bahsediniz. Varsa, kullanacağınız çizim ve gösterimlerinizden örnekler veriniz.

1. Örnek	2. Örnek

2) a) Öğrencilerinizin çözmekte zorlanacağını tahmin ettiğiniz elektrik konusu ile ilgili bir soru oluşturabilir misiniz?
   b) Sizce öğrencileriniz bu soruyu çözmekte neden zorlanıyorlar?
   c) Bu ve benzer soruları kolaylıkla çözebilmeleri için onlara nasıl yardımcı olduğunuzu detaylı bir şekilde anlatınız. Varsa, kullanacağınız çizim ve gösterimlerinizden örnekler veriniz.

3) a) Öğrencilerinizin elektrik konusu kapsamında yer alan ve algılamakta zorlandıkları gündelik yaşamda karşılaştığımız olaylara bir örnek veriniz.

b) Sizce öğrencileriniz bu olayı algılamada neden zorlanıyorlar?

c) Bu zorluğu aşmalarında, öğrencilerinize nasıl yardımcı olduğunuzu detaylı bir şekilde anlatınız. Varsa, kullanacağınız çizim ve gösterimlerinizden örnekler veriniz.

APPENDIX B

INSTRUMENT OF SECOND IMPLEMENTATION

ELEKTRİK KONUSUNA YÖNELİK PEDAGOJİK ALAN BİLGİSİNİ ÖLÇME TESTİ GELİŞTİRME ÇALIŞMALARI

Cinsiyetiniz: ☐ Bay ☐ Bayan

Öğretmenlik Deneyiminiz: _____ yıl

Şu Anda Görev Yaptığınız

Okul Türü: ____

İl: ____

Mezun Olduğunuz Bölüm: ☐ Fizik
☐ Fizik Öğretmenliği
☐ Diğer (Bölüm adını belirtiniz …………………….)

Dersine Girdiğiniz Sınıflar : ☐ 9. Sınıf ☐ 10. Sınıf ☐ 11. Sınıf ☐ 12. Sınıf

Daha önce "Fizik Dersi Öğretim Programları" ile ilgili hizmet içi eğitim kurslarına katıldınız mı? ☐ EVET ☐ HAYIR
Cevabınız "Evet" ise Katılmış Olduğunuz Hizmet İçi Eğitim Kurslarının;

	İlk Katıldığım Kursun	**İkinci Katıldığım Kursun**	**Üçüncü Katıldığım Kursun**	**Dördüncü Katıldığım Kursun**
Süresi				
Yeri				

Lütfen teste başlamadan önce yukarıdaki kutucuğu doldurunuz.
Değerli öğretmenim;

Elinizdeki ankete vereceğiniz cevaplar doğrultusunda fizik öğretmenlerimizin elektrik konusuna yönelik pedagojik alan bilgilerini ölçmek amacında olan bir test oluşturulacaktır. Anketten alacağımız verileri **kesinlikle sizi değerlendirmek amacı ile kullanmayacağız**. Vereceğiniz cevaplar testin geliştirilmesi sürecinde önemli katkılarda bulunacaktır. Bu süreçte size ait hiçbir **kişisel bilgiye ihtiyaç duyulmamaktadır.** Sorulara anlaşılır şekilde kısaca cevap vermeniz yeterlidir. Lütfen her soruya cevap vermeye gayret ediniz.

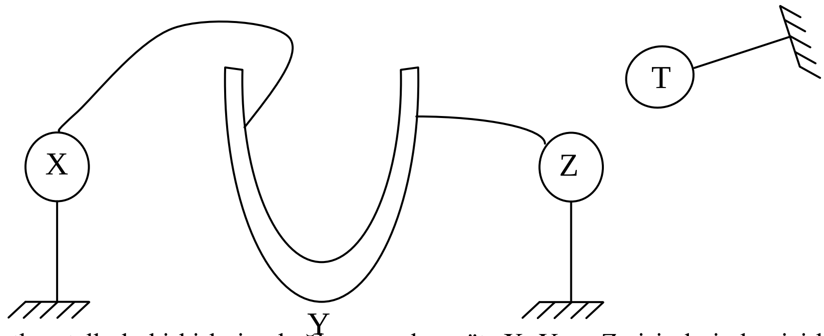
TEŞEKKÜR EDERİM

Eralp Bahçivan

Doktora Öğrencisi

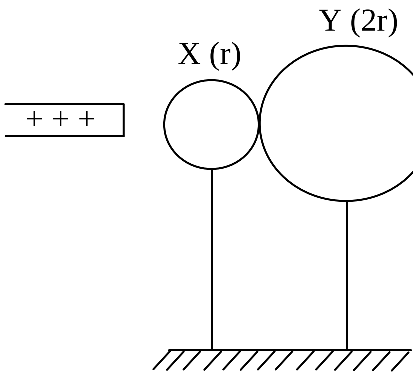
OFMAE-Orta Doğu Teknik Üniversitesi

1)



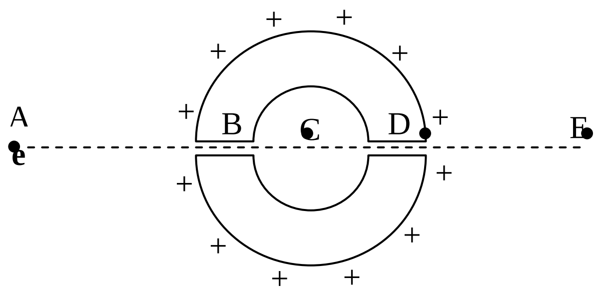
Şekildeki gibi iletken tellerle birbirlerine bağlanmış olan nötr X, Y ve Z cisimlerinden içi boş Y iletkenine (–) yüklü T cisminin içeriden dokundurulduğu bir sistemde cisimlerin son yüklerinin işaretlerinin ne olduğunu sınıfta soruyorsunuz. Öğrencilerinizin bir kısmı X ve T'nin nötr, Y ve Z'nin (–) yüklü olacağını söylüyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?

2)



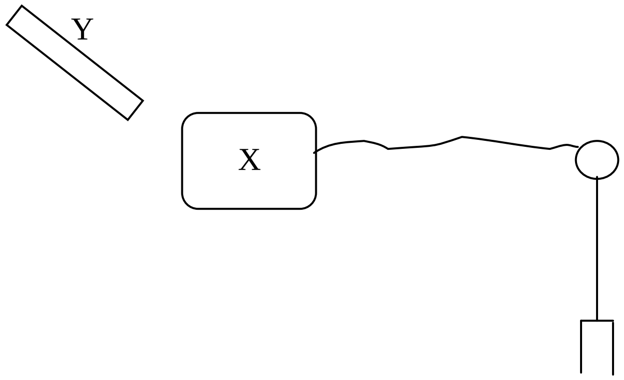
Nötr ve birbirine dokunmakta olan iletken X ve Y cisimleri sırası ile r ve 2r yarıçaplıdır. (+) yüklü çubuk sisteme yaklaştırılınca X ve Y'nin yük işaretleri ve miktarları arasındaki ilişkinin nasıl olacağını soruyorsunuz. Öğrencilerinizden bir kısmı X'te –q olursa Y'de +2q yük bulunur diyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?

3)



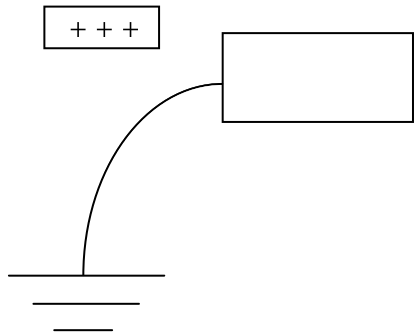
(+) yüklü, içi boş ve C merkezli olan iletken küreyi tahtaya çiziyorsunuz. A noktasında bulunan elektronun, serbest bırakıldığı bir durumda AB, BC, CD ve DE doğrusal yolları boyunca nasıl hareket edeceğini soruyorsunuz. Öğrencilerinizin bir kısmı elektronun bu aralıklardaki hareketinin sırası ile hızlanır, yavaşlar, hızlanır ve yavaşlar şeklinde cevaplıyor. Sizce bu öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?

4)

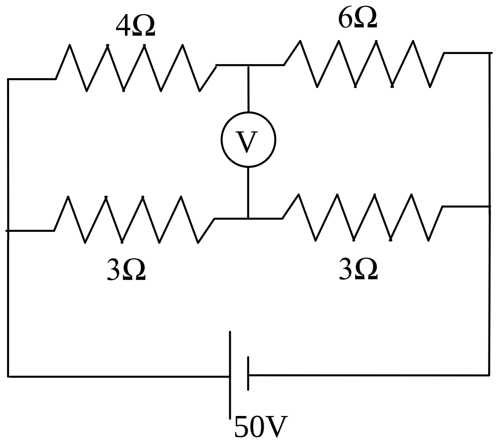


Nötr X cismi iletken bir tel yardımı ile nötr elektroskopa bağlanıyor. Öğrencilerinize (–) yüklü Y çubuğu sisteme şekildeki gibi yaklaştırılınca X cisminin, elektroskopun topuzunun ve yapraklarının nasıl yükleneceğini soruyorsunuz. Bazı öğrencileriniz sırası ile (+), (–), (–) şeklinde yüklenme gerçekleşeceğini belirtiyorlar. Sizce bu öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?

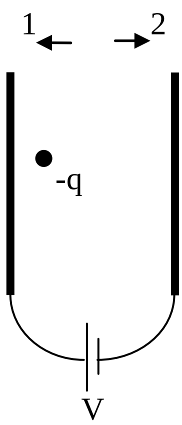
5) Toprağa bağlı iletken bir cisme şekildeki gibi (+) yüklü cismin yaklaştırıldığı bir sistemde bir süre sonra toprak bağlantısı kesiliyor ve (+) yüklü cisim sistemden uzaklaştırılıyor. Sınıf içerisinde iletken cismin son yük işaretini soruyorsunuz ve öğrencilerinizin bir kısmı (+) yüklü olur şeklinde cevap veriyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



6) Yandaki elektrik devresini tahtaya çiziyorsunuz ve voltmetrenin göstereceği değerin ne olacağını soruyorsunuz. Öğrencilerinizin bir kısmı soruya cevap veremiyor. Sizce öğrencileriniz hangi sebeplerden dolayı bu soruya cevap veremiyorlar?

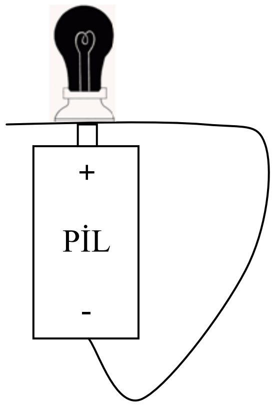


7) Yatay ve sürtünmesiz düzlemde –q yüklü cisim serbest bırakılıyor. Öğrencilerinize cismin hangi yönde hareket edeceğini soruyorsunuz ve bir kısmı 2 yönünde hareket eder şeklinde cevap veriyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?

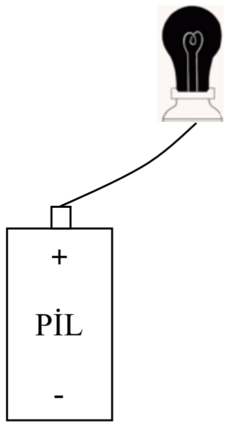


8) Fizik dersinde, barajlarda üretilen elektrik enerjisinin yüksek gerilimle şehirlere taşındığını, bunun sebebinin ise enerji kaybını azaltmak olduğunu anlatıyorsunuz. Öğrencilerinizin bir kısmı yüksek gerilimin yüksek akım şiddetine sebep olacağını bunun da enerji kaybını artıracağını belirtiyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?

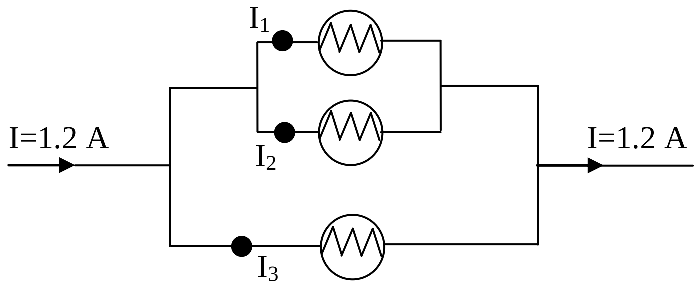
9) Öğrencilerinizin bir kısmı yandaki devrede ampulün ışık vereceğini belirtiyorlar. Sizce hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



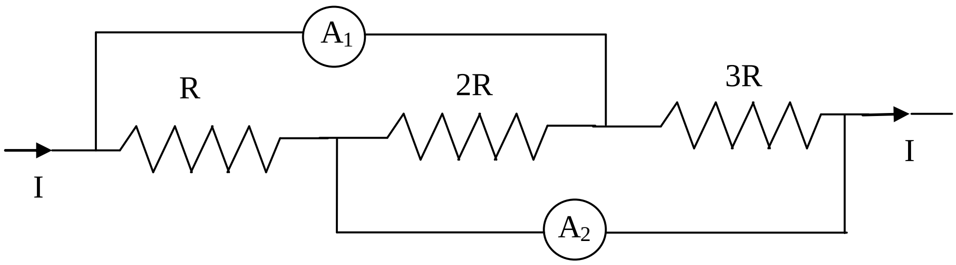
10) Öğrencilerinizin bir kısmı yandaki devrede ampulün ışık vereceğini belirtiyorlar. Sizce hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



11) Özdeş lambalardan oluşan yandaki devrede I_1, I_2 ve I_3 akımlarının şiddetlerini sordunuz ve bazı öğrencileriniz bu akımların değerinin sırasıyla 0.3 A, 0.3 A, 0.6 A olacağını söylediler. Sizce bu öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



12)



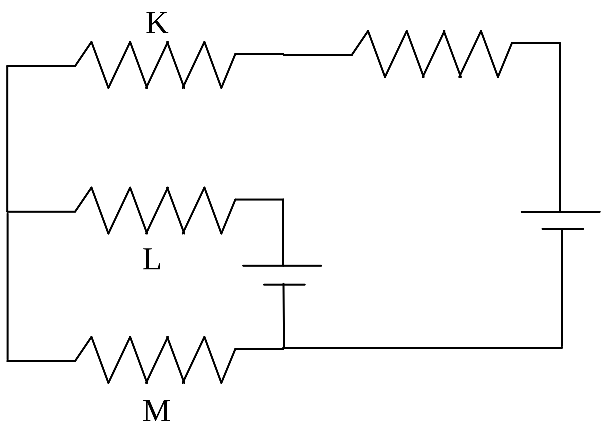
Şekildeki devrede A_1 ve A_2 ampermetrelerinin göstereceği değerler arasındaki oranın ne olacağını soruyorsunuz. Öğrencilerinizin bir kısmı soruya cevap veremiyor. Onlara bu soruyu rahatlıkla çözebilmelerini sağlayacak yöntemler gösterir misiniz?

13) Dirençlerin bağlanması ile ilgili olarak, öğrencilerinizin birçoğu, basit devrelerde (sadece paralel ya da sadece seri bağlı dirençlerin bulunduğu devreler) rahatlıkla sorulanları cevaplayabiliyorlar. Ancak aynı öğrenciler dirençlerin karışık bağlandığı devrelerde zorlanıyorlar.

a) Öğrencilerinizin zorlanmalarının sebepleri neler olabilir?

b) Bu zorlukları aşmaları için kullanacağınız yöntemler nelerdir olabilir?

14) Özdeş üreteç ve dirençlerden oluşan şekildeki devrede dirençlerin üzerinden geçen akımların şiddetleri arasındaki sıralamanın nasıl olacağını soruyorsunuz. Öğrencilerinizin bir kısmı soruya cevap veremiyor. Onlara bu soruyu rahatlıkla çözebilmelerini sağlayacak yöntemler gösterir misiniz?

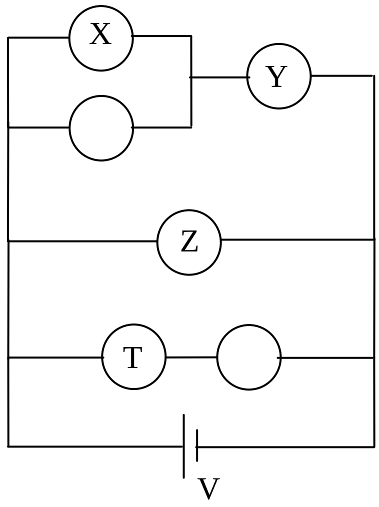


15) Bazı öğrencileriniz yıldırım olayında yük hareketinin sadece buluttan yere doğru olduğunu belirtiyorlar.

a) Öğrencilerinizin bu şekilde düşünmelerinin sebepleri neler olabilir?

b) Bu zorlukları aşmaları için kullanacağınız yöntemler neler olabilir?

16) Şekildeki devrede verilen özdeş lambalardan X, Y, Z ve T'nin parlaklıklarını sıralamalarını istiyorsunuz ve öğrencilerinizin bir kısmı soruya cevap veremiyor. Onlara bu soruyu rahatlıkla çözebilmelerini sağlayacak yöntemler gösterir misiniz?



17) Ders esnasında öğrencilerinizin bir kısmının "potansiyel fark" ve "noktanın potansiyeli" kavramlarını karıştırdığını fark ettiniz.

a) Sizce öğrencileriniz neden bu iki kavram arasında bir karmaşa yaşıyordur?

b) Öğrencilerinizin bu zorluğun üstesinden gelebilmeleri için yapacağınız uygulamalar neler olabilir?

18) Ders esnasında öğrencilerinizin bir kısmının “potansiyel” ve “elektromotor kuvvet” kavramlarını karıştırdığını fark ettiniz.

a) Sizce öğrencileriniz neden bu iki kavram arasında bir karmaşa yaşıyor?

b) Öğrencilerinizin bu zorluğun üstesinden gelebilmeleri için yapacağınız uygulamalar neler olabilir?

19) Aşağıdaki tabloda, sol sütunda, elektrik konusu kapsamında öğrencilerde sıklıkla karşılaşılan kavram yanılgılarından bazıları verilmiştir. Her kavram yanılgısını en fazla iki cümle ile çürütür müsünüz?

Kavram Yanılgısı	**Çürütücü İfade**
Elektronlar ışık hızında hareket eder.	
Nötr cisimlerde yük yoktur.	
Elektrik akımı, dirençlerde harcanır.	
Elektrik akımı, potansiyel farkın değişimi sonucu oluşur.	
Elektrik akımının miktarı değiştirilerek, devrenin potansiyel farkı değiştirilir.	

APPENDIX C

INSTRUMENT OF THIRD IMPLEMENTATION

ELEKTRİK KONUSUNA YÖNELİK PEDAGOJİK ALAN BİLGİSİNİ ÖLÇME TESTİ GELİŞTİRME ÇALIŞMALARI

Cinsiyetiniz: ☐ Bay ☐ Bayan

Öğretmenlik Deneyiminiz: _____ yıl

Şu Anda Görev Yaptığınız

Okul Türü: ____________________________________

İl: ____

Mezun Olduğunuz Bölüm: ☐ Fizik
☐ Fizik Öğretmenliği
☐ Diğer (Bölüm adını belirtiniz …………………….)

Dersine Girdiğiniz Sınıflar : ☐ 9. Sınıf ☐ 10. Sınıf ☐ 11. Sınıf ☐ 12. Sınıf

Daha önce "Fizik Dersi Öğretim Programları" ile ilgili hizmet içi eğitim kurslarına katıldınız mı? ☐ EVET ☐ HAYIR

Cevabınız "Evet" ise Katılmış Olduğunuz Hizmet İçi Eğitim Kurslarının;

	İlk Katıldığım Kursun	**İkinci Katıldığım Kursun**	**Üçüncü Katıldığım Kursun**	**Dördüncü Katıldığım Kursun**
Süresi				
Yeri				

Lütfen teste başlamadan önce yukarıdaki kutucuğu doldurunuz.

Değerli öğretmenim;

Elinizdeki ankete vereceğiniz cevaplar doğrultusunda fizik öğretmenlerimizin elektrik konusuna yönelik pedagojik alan bilgilerini ölçmek amacında olan bir test oluşturulacaktır. Anketten alacağımız verileri **kesinlikle sizi değerlendirmek amacı ile kullanmayacağız**. Vereceğiniz cevaplar testin geliştirilmesi sürecinde önemli katkılarda bulunacaktır. Bu süreçte size ait hiçbir **kişisel bilgiye ihtiyaç duyulmamaktadır.** Sorulara anlaşılır şekilde kısaca cevap vermeniz yeterlidir. **Anketi cevaplandırdıktan sonra cevaplama süreci için harcadığınız zamanı alttaki kutucuğa yazınız.** Lütfen her soruya cevap vermeye gayret ediniz.

Anketi Cevaplandırma Süresi: ____ dakika

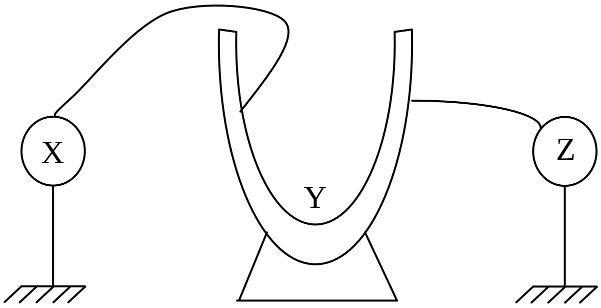
TEŞEKKÜR EDERİM

Eralp Bahçivan

Doktora Öğrencisi

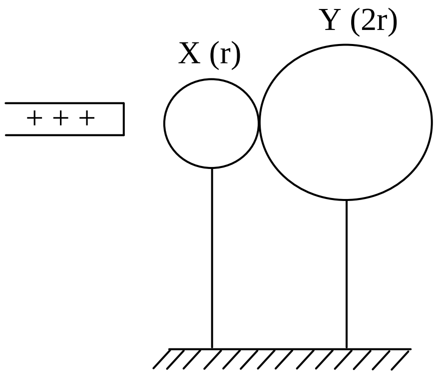
OFMAE-Orta Doğu Teknik Üniversitesi

1)



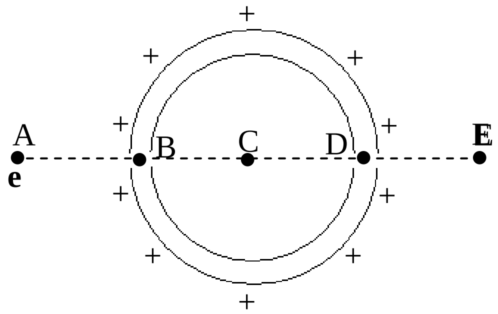
Şekildeki gibi iletken tellerle birbirlerine bağlanmış olan nötr X, Y ve Z cisimlerinden içi boş Y iletkenine (–) yüklü bir cismin içeriden dokundurulduğu bir sistemde cisimlerin son yüklerinin işaretlerinin ne olacağını sınıfta soruyorsunuz. Öğrencilerinizin bir kısmı X'in nötr, Y ve Z'nin (–) yüklü olacağını söylüyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?

2)



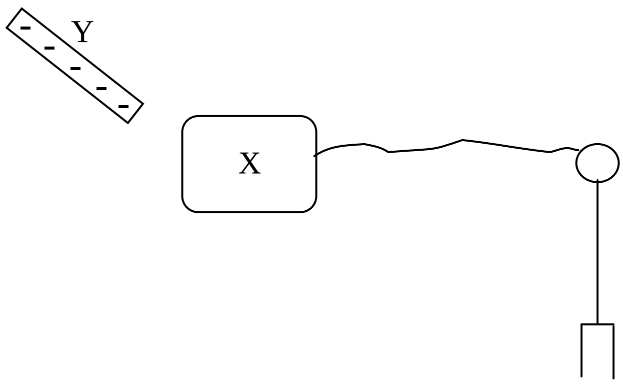
Nötr ve birbirine dokunmakta olan iletken X ve Y cisimleri sırası ile r ve 2r yarıçaplıdır. (+) yüklü çubuk sisteme yaklaştırılınca X ve Y'nin yük işaretleri ve miktarları arasındaki ilişkinin nasıl olacağını soruyorsunuz. Öğrencilerinizden bir kısmı X'te –q olursa Y'de +2q yük bulunur diyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?

3)



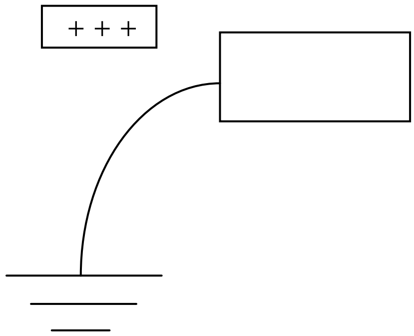
Yatay ve sürtünmesiz düzlem üzerinde duran (+) yüklü, içi boş ve C merkezli olan iletken küreyi tahtaya çiziyorsunuz. A noktasında bulunan elektronun, serbest bırakıldığı bir durumda AB, BC, CD ve DE doğrusal yolları boyunca nasıl hareket edeceğini soruyorsunuz. Öğrencilerinizin bir kısmı elektronun bu aralıklardaki hareketinin sırası ile hızlanır, yavaşlar, hızlanır ve yavaşlar şeklinde cevaplıyor. Sizce bu öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?

4)

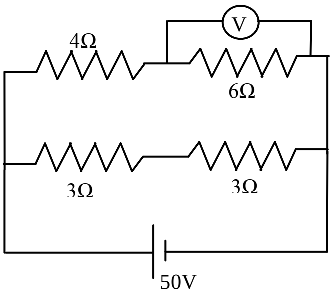


Nötr X cismi iletken bir tel yardımı ile nötr elektroskopa bağlanıyor. Öğrencilerinize (–) yüklü Y çubuğu sisteme şekildeki gibi yaklaştırılınca X cisminin, elektroskopun topuzunun ve yapraklarının nasıl yükleneceğini soruyorsunuz. Bazı öğrencileriniz sırası ile (+), (–), (–) şeklinde yüklenme gerçekleşeceğini belirtiyorlar. Sizce bu öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?

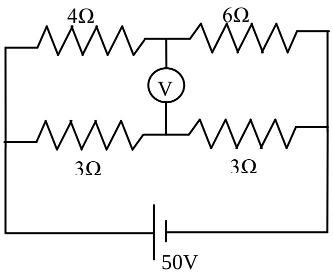
5) Toprağa bağlı iletken bir cisme şekildeki gibi (+) yüklü cismin yaklaştırıldığı bir sistemde bir süre sonra toprak bağlantısı kesiliyor ve (+) yüklü cisim sistemden uzaklaştırılıyor. Sınıf içerisinde iletken cismin son yük işaretini soruyorsunuz ve öğrencilerinizin bir kısmı (+) yüklü olur şeklinde cevap veriyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



6) Yandaki elektrik devrelerini tahtaya çiziyorsunuz ve voltmetrelerin göstereceği değerleri soruyorsunuz. Öğrencilerinizin bir kısmı **yalnızca** Şekil I'deki voltmetrenin değerini hesaplayabiliyorlar. Sizce bu öğrencileriniz Şekil II'deki voltmetrenin değerini neden hesaplayamıyorlar?

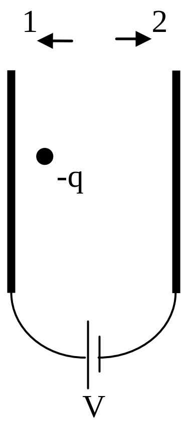


Şekil I

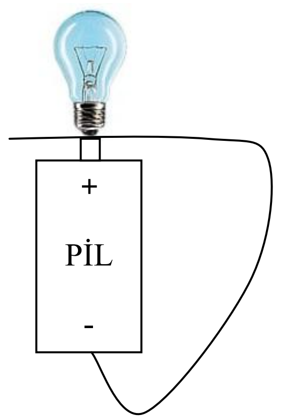


Şekil II

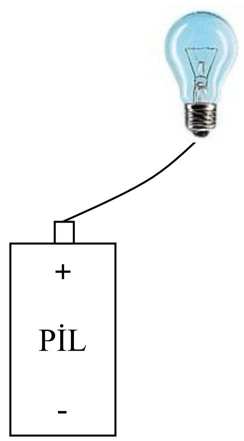
7) Yatay ve sürtünmesiz düzlemde –q yüklü cisim serbest bırakılıyor. Öğrencilerinize cismin hangi yönde hareket edeceğini soruyorsunuz ve bir kısmı 2 yönünde hareket eder şeklinde cevap veriyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



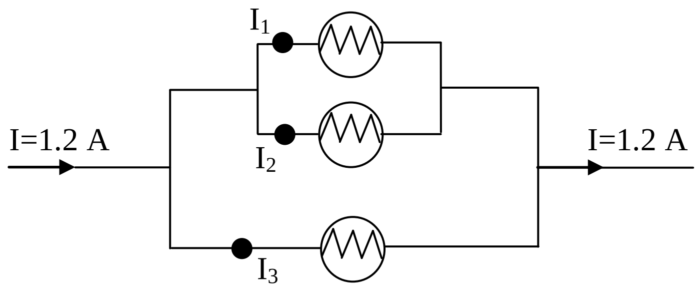
8) Öğrencilerinizin bir kısmı yandaki devrede ampulün ışık vereceğini belirtiyorlar. Sizce hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



9) Öğrencilerinizin bir kısmı yandaki devrede ampulün ışık vereceğini belirtiyorlar. Sizce hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



10) Özdeş lambalardan oluşan yandaki devrede I_1, I_2 ve I_3 akımlarının şiddetlerini sordunuz ve bazı öğrencileriniz bu akımların değerinin sırasıyla 0.3 A, 0.3 A, 0.6 A olacağını söylediler. Sizce bu öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?

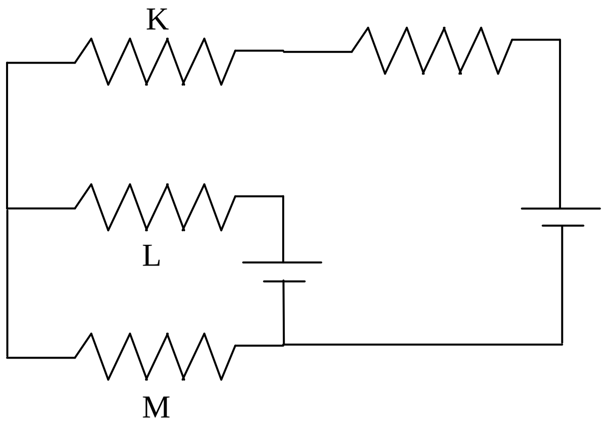


11) Dirençlerin bağlanması ile ilgili olarak, öğrencilerinizin birçoğu, basit devrelerde (sadece paralel ya da sadece seri bağlı dirençlerin bulunduğu devreler) rahatlıkla sorulanları cevaplayabiliyorlar. Ancak aynı öğrenciler dirençlerin karışık bağlandığı devrelerde zorlanıyorlar.

a) Öğrencilerinizin zorlanmalarının sebepleri neler olabilir?

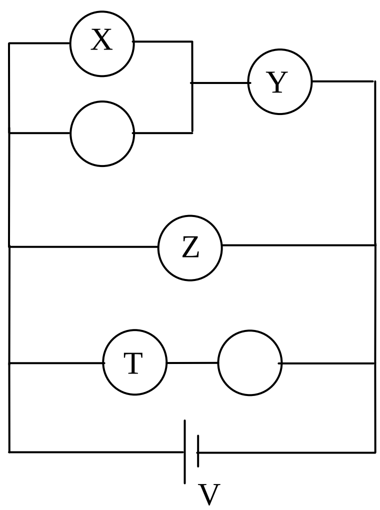
b) Bu zorlukları aşmaları için kullanacağınız yöntemler nelerdir olabilir?

12) Özdeş üreteç ve dirençlerden oluşan şekildeki devrede dirençlerin üzerinden geçen akımların şiddetleri arasındaki sıralamanın nasıl olacağını soruyorsunuz. Öğrencilerinizin bir kısmı soruya cevap veremiyor. Onlara bu soruyu rahatlıkla çözebilmelerini sağlayacak yöntemler gösterir misiniz?



13) Derste, barajlarda üretilen elektrik enerjisinin yüksek gerilimle şehirlere taşındığını, bunun sebebinin ise enerji kaybını azaltmak olduğunu ifade ettiniz. Öğrencilerinizin bir kısmı yüksek gerilimin enerji kaybını artıracağını belirtiyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?

14) Şekildeki devrede verilen özdeş lambalardan X, Y, Z ve T'nin parlaklıklarını sıralamalarını istiyorsunuz ve öğrencilerinizin bir kısmı soruya cevap veremiyor. Onlara bu soruyu rahatlıkla çözebilmelerini sağlayacak yöntemler gösterir misiniz?



15) Ders esnasında öğrencilerinizin bir kısmının “potansiyel fark” ve “noktanın potansiyeli” kavramlarını karıştırdığını fark ettiniz.

a) Sizce öğrencileriniz neden bu iki kavram arasında bir karmaşa yaşıyordur?

b) Öğrencilerinizin bu zorluğun üstesinden gelebilmeleri için yapacağınız uygulamalar neler olabilir?

16) Aşağıdaki tabloda, sol sütunda, elektrik konusu kapsamında öğrencilerde sıklıkla karşılaşılan kavram yanılgılarından bazıları verilmiştir. Her kavram yanılgısını en fazla iki cümle ile çürütür müsünüz?

Kavram Yanılgısı	**Çürütücü İfade**
Bir elektrik devresinde elektronlar ışık hızında hareket eder.	
Nötr cisimlerde yük yoktur.	
Elektrik akımı, dirençlerde harcanır.	
Elektrik akımının oluşabilmesi için potansiyel farkın değişmesi gerekir.	
Elektrik akımının miktarı değiştirilerek, devrenin potansiyel farkı değiştirilir.	

APPENDIX D

INSTRUMENT OF FINAL IMPLEMENTATION

ELEKTRİK KONUSUNA YÖNELİK PEDAGOJİK ALAN BİLGİSİNİ ÖLÇME TESTİ

Cinsiyetiniz: ☐ Bay ☐ Bayan

Öğretmenlik Deneyiminiz: _____ yıl

Şu Anda Görev Yaptığınız

Okul Türü: ____________________________________

İl: ____________________________________

Mezun Olduğunuz Bölüm: ☐ Fizik
☐ Fizik Öğretmenliği
☐ Diğer (Bölüm adını belirtiniz …………………….)

Dersine Girdiğiniz Sınıflar : ☐ 9. Sınıf ☐ 10. Sınıf ☐ 11. Sınıf ☐ 12. Sınıf

Daha önce "Fizik Dersi Öğretim Programları" ile ilgili hizmet içi eğitim kurslarına katıldınız mı? ☐ EVET ☐ HAYIR

Cevabınız "Evet" ise Katılmış Olduğunuz Hizmet İçi Eğitim Kurslarının;

	İlk Katıldığım Kursun	**İkinci Katıldığım Kursun**	**Üçüncü Katıldığım Kursun**	**Dördüncü Katıldığım Kursun**
Süresi				
Yeri				

Lütfen teste başlamadan önce yukarıdaki kutucuğu doldurunuz.

Değerli öğretmenim;

Elinizdeki ankete vereceğiniz cevaplar doğrultusunda fizik öğretmenlerimizin elektrik konusuna yönelik pedagojik alan bilgilerini ölçmek amacında olan bir test oluşturulacaktır. Anketten alacağımız verileri **kesinlikle sizi değerlendirmek amacı ile kullanmayacağız**. Vereceğiniz cevaplar testin geliştirilmesi sürecinde önemli katkılarda bulunacaktır. Bu süreçte size ait hiçbir **kişisel bilgiye ihtiyaç duyulmamaktadır.** Sorulara anlaşılır şekilde kısaca cevap vermeniz yeterlidir. **Anketi cevaplandırdıktan sonra cevaplama süreci için harcadığınız zamanı alttaki kutucuğa yazınız.** Lütfen her soruya cevap vermeye gayret ediniz.

Anketi Cevaplandırma Süresi: ____ dakika

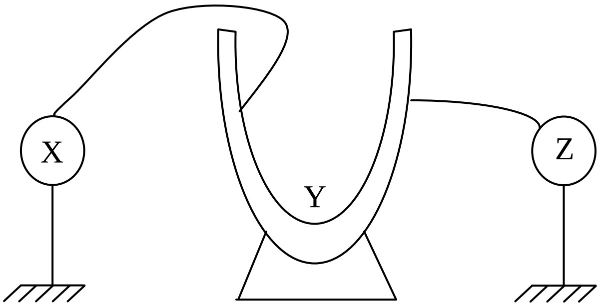
TEŞEKKÜR EDERİM

Eralp Bahçivan

Doktora Öğrencisi

OFMAE-Orta Doğu Teknik Üniversitesi

1) Şekildeki gibi iletken tellerle birbirlerine bağlanmış olan nötr X, Y ve Z cisimlerinden içi boş Y iletkenine (–) yüklü iletken bir cismin içeriden dokundurulduğu sistemde cisimlerin son yüklerinin işaretlerinin ne olacağını sınıfta soruyorsunuz. Öğrencilerinizin bir kısmı X'in nötr, Y ve Z'nin (–) yüklü olacağını söylüyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



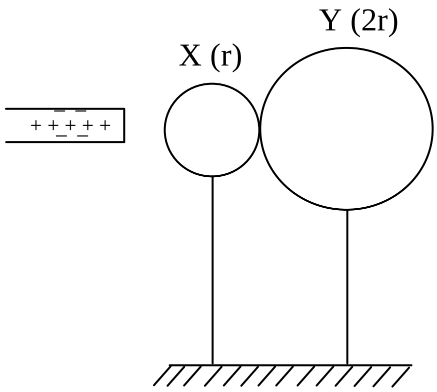
Bu soruya cevap verirken faydalandığınız bilgi kaynağının ne olduğunu belirtiniz.

☐ Kendi öğrencilerim ile ilgili deneyimlerime dayanarak cevap veriyorum.

☐ Bu öğrenci hatası ile daha önce hiç karşılaşmadım. Akıl yürüterek cevap veriyorum.

☐ Diğer *(Lütfen belirtiniz)*…………………………………………………………………..

2) Nötr ve birbirine dokunmakta olan iletken X ve Y cisimleri sırası ile r ve 2r yarıçaplıdır. (+) yüklü çubuk sisteme yaklaştırılınca X ve Y'nin yük işaretleri ve miktarları arasındaki ilişkinin nasıl olacağını soruyorsunuz. Öğrencilerinizden bir kısmı X'te –q olursa Y'de +2q yük bulunur diyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



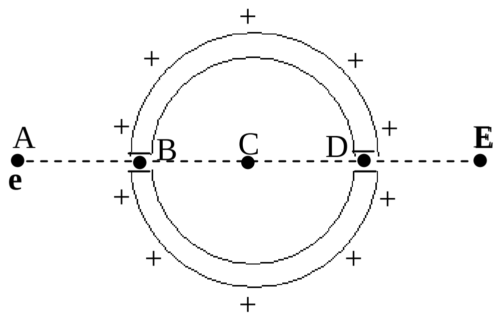
Bu soruya cevap verirken faydalandığınız bilgi kaynağının ne olduğunu belirtiniz.

☐ Kendi öğrencilerim ile ilgili deneyimlerime dayanarak cevap veriyorum.

☐ Bu öğrenci hatası ile daha önce hiç karşılaşmadım. Akıl yürüterek cevap veriyorum.

☐ Diğer *(Lütfen belirtiniz)*……………………………………………………………….

3) Yatay ve sürtünmesiz düzlem üzerinde duran (+) yüklü, içi boş ve C merkezli olan iletken küreyi tahtaya çiziyorsunuz. A noktasında bulunan elektronun, serbest bırakıldığı bir durumda AB, BC, CD ve DE doğrusal yolları boyunca nasıl hareket edeceğini soruyorsunuz. Öğrencilerinizin bir kısmı elektronun bu aralıklardaki hareketinin sırası ile hızlanır, yavaşlar, hızlanır ve yavaşlar şeklinde olacağını belirtiyor. Sizce bu öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



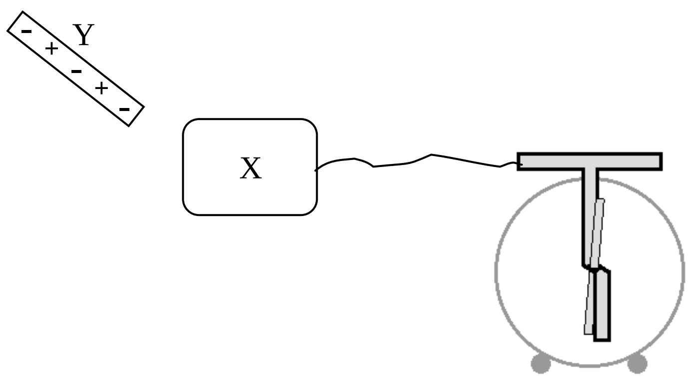
Bu soruya cevap verirken faydalandığınız bilgi kaynağının ne olduğunu belirtiniz.

☐ Kendi öğrencilerim ile ilgili deneyimlerime dayanarak cevap veriyorum.

☐ Bu öğrenci hatası ile daha önce hiç karşılaşmadım. Akıl yürüterek cevap veriyorum.

☐ Diğer *(Lütfen belirtiniz)*…………………………………………………………………..

4) Nötr iletken X cismi iletken bir tel yardımı ile nötr elektroskoba bağlanıyor. Öğrencilerinize (–) yüklü Y çubuğu sisteme şekildeki gibi yaklaştırılınca X cisminin, elektroskobun topuzunun ve yapraklarının geçici olarak nasıl yükleneceğini soruyorsunuz. Bazı öğrencileriniz sırası ile (+), (–), (–) şeklinde yüklenme gerçekleşeceğini belirtiyorlar. Sizce bu öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



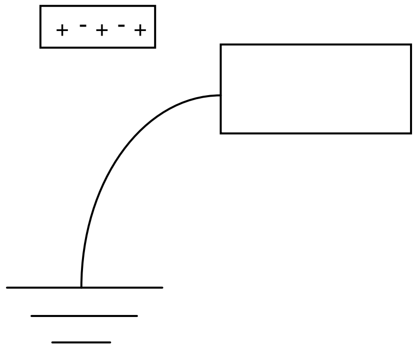
Bu soruya cevap verirken faydalandığınız bilgi kaynağının ne olduğunu belirtiniz.

☐ Kendi öğrencilerim ile ilgili deneyimlerime dayanarak cevap veriyorum.

☐ Bu öğrenci hatası ile daha önce hiç karşılaşmadım. Akıl yürüterek cevap veriyorum.

☐ Diğer *(Lütfen belirtiniz)*…………………………………………………………………..

5) Toprağa bağlı iletken bir cisme şekildeki gibi (+) yüklü cismin yaklaştırıldığı bir sistemde bir süre sonra toprak bağlantısı kesiliyor ve (+) yüklü cisim sistemden uzaklaştırılıyor. Sınıf içerisinde iletken cismin son yük işaretini soruyorsunuz ve öğrencilerinizin bir kısmı (+) yüklü olur şeklinde cevap veriyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



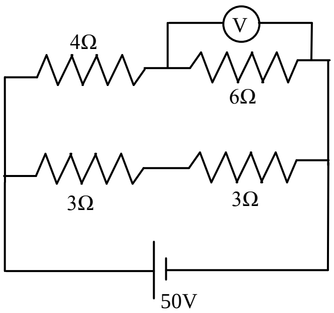
Bu soruya cevap verirken faydalandığınız bilgi kaynağının ne olduğunu belirtiniz.

☐ Kendi öğrencilerim ile ilgili deneyimlerime dayanarak cevap veriyorum.

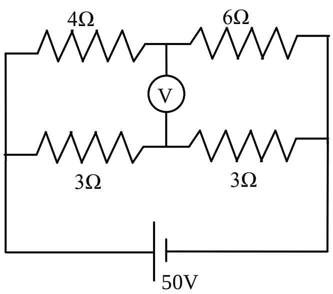
☐ Bu öğrenci hatası ile daha önce hiç karşılaşmadım. Akıl yürüterek cevap veriyorum.

☐ Diğer *(Lütfen belirtiniz)*…………………………………………………………………..

6) Yandaki elektrik devrelerini tahtaya çiziyorsunuz ve voltmetrelerin göstereceği değerleri soruyorsunuz. Öğrencilerinizin bir kısmı **yalnızca** Şekil I'deki voltmetrenin değerini hesaplayabiliyorlar. Sizce bu öğrencileriniz Şekil II'deki voltmetrenin değerini neden hesaplayamıyorlar?



Şekil I



Şekil II

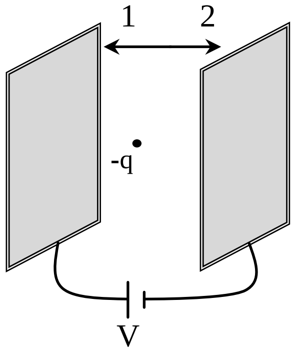
Bu soruya cevap verirken faydalandığınız bilgi kaynağının ne olduğunu belirtiniz.

☐ Kendi öğrencilerim ile ilgili deneyimlerime dayanarak cevap veriyorum.

☐ Bu öğrenci zorluğu ile daha önce hiç karşılaşmadım. Akıl yürüterek cevap veriyorum.

☐ Diğer *(Lütfen belirtiniz)*…………………………………………………………………..

7) Yerçekimsiz ortamda şekildeki gibi paralel levhalar arasında bulunan –q yüklü cisim serbest bırakılıyor. Öğrencilerinize cismin hangi yönde hareket edeceğini soruyorsunuz ve bir kısmı 2 yönünde hareket eder şeklinde cevap veriyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



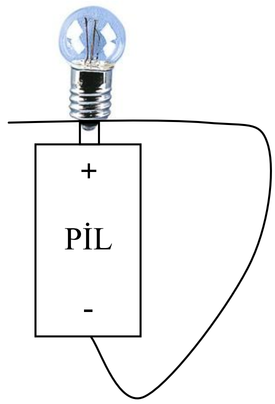
Bu soruya cevap verirken faydalandığınız bilgi kaynağının ne olduğunu belirtiniz.

☐ Kendi öğrencilerim ile ilgili deneyimlerime dayanarak cevap veriyorum.

☐ Bu öğrenci hatası ile daha önce hiç karşılaşmadım. Akıl yürüterek cevap veriyorum.

☐ Diğer *(Lütfen belirtiniz)*……………………………………………………………………..

8) Öğrencilerinizin bir kısmı yandaki devrede ampulün ışık vereceğini belirtiyorlar. Sizce hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



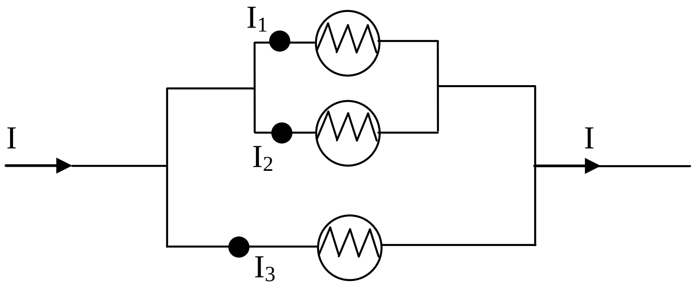
Bu soruya cevap verirken faydalandığınız bilgi kaynağının ne olduğunu belirtiniz.

☐ Kendi öğrencilerim ile ilgili deneyimlerime dayanarak cevap veriyorum.

☐ Bu öğrenci hatası ile daha önce hiç karşılaşmadım. Akıl yürüterek cevap veriyorum.

☐ Diğer *(Lütfen belirtiniz)*…………………………………………………………………….

9) Özdeş lambalardan oluşan yandaki devrede I_1, I_2 ve I_3 akımlarının şiddetleri arasındaki ilişkiyi sordunuz ve bazı öğrencileriniz bu akımların şiddetlerinin birbirinden farklı olacağını belirtti. Sizce bu öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?



Bu soruya cevap verirken faydalandığınız bilgi kaynağının ne olduğunu belirtiniz.

☐ Kendi öğrencilerim ile ilgili deneyimlerime dayanarak cevap veriyorum.

☐ Bu öğrenci hatası ile daha önce hiç karşılaşmadım. Akıl yürüterek cevap veriyorum.

☐ Diğer *(Lütfen belirtiniz)*…………………………………………………………………..

10) Derste, barajlarda üretilen elektrik enerjisinin yüksek gerilimle şehirlere taşındığını, bunun sebebinin ise enerji kaybını azaltmak olduğunu ifade ettiniz. Öğrencilerinizin bir kısmı yüksek gerilimin enerji kaybını artıracağını belirtiyor. Sizce öğrencileriniz hangi düşüncelerinden dolayı bu hatalı sonuca ulaşıyorlar?

Bu soruya cevap verirken faydalandığınız bilgi kaynağının ne olduğunu belirtiniz.

☐ Kendi öğrencilerim ile ilgili deneyimlerime dayanarak cevap veriyorum.

☐ Bu öğrenci hatası ile daha önce hiç karşılaşmadım. Akıl yürüterek cevap veriyorum.

☐ Diğer *(Lütfen belirtiniz)*…………………………………………………………………..

11) Dirençlerin bağlanması ile ilgili olarak, öğrencilerinizin birçoğu, basit devrelerde (sadece paralel ya da sadece seri bağlı dirençlerin bulunduğu devreler) rahatlıkla soruları cevaplayabiliyorlar. Ancak aynı öğrenciler dirençlerin karışık bağlandığı devrelerde zorlanıyorlar. Öğrencilerin bu zorluğunu dikkate alarak;

konuyu yeni bir öğrenci grubuna ilk defa anlatacak olsanız, dersinizi nasıl işlerdiniz?	*konuyu tekrar anlatmanız gerekseydi dersinizi nasıl işlerdiniz?*

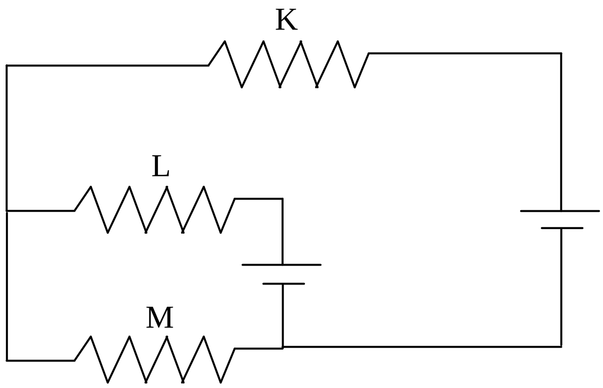
Bu soruya cevap verirken faydalandığınız bilgi kaynağının ne olduğunu belirtiniz.

☐ Kendi öğrencilerim ile ilgili deneyimlerime dayanarak cevap veriyorum.

☐ Bu öğrenci zorluğu ile daha önce hiç karşılaşmadım. Akıl yürüterek cevap veriyorum.

☐ Diğer *(Lütfen belirtiniz)*……………………………………………………………………..

12) Özdeş üreteç ve dirençlerden oluşan şekildeki devrede K ve L dirençlerinin üzerinden geçen akımların şiddetleri arasındaki ilişkinin nasıl olacağını soruyorsunuz. Öğrencilerinizin bir kısmı soruya cevap veremiyor veya yanlış cevap veriyor. Öğrencilerinizin bu zorluğunu dikkate alarak;



konuyu <u>yeni bir öğrenci grubuna ilk defa</u> anlatacak olsanız, dersinizi nasıl işlerdiniz?	*konuyu <u>tekrar</u> anlatmanız gerekseydi dersinizi nasıl işlerdiniz?*

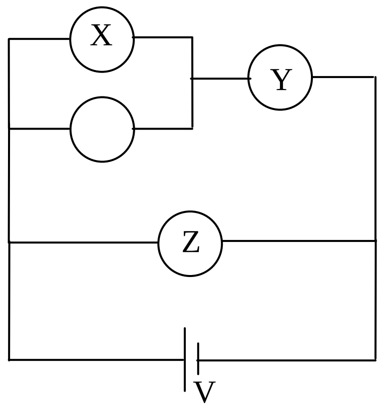
Bu soruya cevap verirken faydalandığınız bilgi kaynağının ne olduğunu belirtiniz.

☐ Kendi öğrencilerim ile ilgili deneyimlerime dayanarak cevap veriyorum.

☐ Bu öğrenci zorluğu ile daha önce hiç karşılaşmadım. Akıl yürüterek cevap veriyorum.

☐ Diğer *(Lütfen belirtiniz)*………………………………………………………………

13) Şekildeki devrede verilen özdeş lambalardan X, Y ve Z'nin parlaklıklarını sıralamalarını istiyorsunuz ve öğrencilerinizin bir kısmı soruya cevap veremiyor veya yanlış cevap veriyor. Öğrencilerinizin bu zorluğunu dikkate alarak;



konuyu <u>*yeni bir öğrenci grubuna ilk defa*</u> *anlatacak olsanız, dersinizi nasıl işlerdiniz?*	*konuyu* <u>*tekrar*</u> *anlatmanız gerekseydi dersinizi nasıl işlerdiniz?*

Bu soruya cevap verirken faydalandığınız bilgi kaynağının ne olduğunu belirtiniz.

☐ Kendi öğrencilerim ile ilgili deneyimlerime dayanarak cevap veriyorum.

☐ Bu öğrenci zorluğu ile daha önce hiç karşılaşmadım. Akıl yürüterek cevap veriyorum.

☐ Diğer *(Lütfen belirtiniz)*…………………………………………………………………..

14) Ders esnasında öğrencilerinizin bir kısmının "potansiyel fark" ve "noktanın potansiyeli" kavramlarını karıştırdığını fark ettiniz. Öğrencilerinizin bu kavram karmaşasını dikkate alarak;

konuyu *yeni bir öğrenci grubuna ilk defa* *anlatacak olsanız, dersinizi nasıl işlerdiniz?*	*konuyu* *tekrar* *anlatmanız gerekseydi dersinizi nasıl işlerdiniz?*

Bu soruya cevap verirken faydalandığınız bilgi kaynağının ne olduğunu belirtiniz.

☐ Kendi öğrencilerim ile ilgili deneyimlerime dayanarak cevap veriyorum.

☐ Bu öğrenci hatası ile daha önce hiç karşılaşmadım. Akıl yürüterek cevap veriyorum.

☐ Diğer *(Lütfen belirtiniz)*……………………………………………………………………..

15) Aşağıdaki tabloda, sol sütunda verilen her kavram ile ilgili olarak **bu dokümanda geçmeyen** bir kavram yanılgısı yazdıktan sonra bu kavram yanılgısını en fazla iki cümle ile çürütür müsünüz?

Kavram	**Kavram Yanılgısı**	**Çürütücü İfade**
Elektrik akımı		
Potansiyel fark		
Elektrostatik Kuvvet		

APPENDIX E*

JSI AND PSEI ITEMS

YÖNERGE: Bu ölçekte, öğretmenlik mesleği ile ilgili bazı ifadeler yer almaktadır. Bu ifadeler "tamamen katılıyorum" ile "hiç katılmıyorum" arasında 5 dereceye ayrılmıştır. Lütfen her bir ifadeyi dikkatlice okuyup, sizin için en uygun olan dereceyi işaretleyiniz.	**Kesinlikle Katılmıyorum**	**Katılmıyorum**	**Kararsızım**	**Katılıyorum**	**Kesinlikle Katılıyorum**
1) Öğretim hedeflerimi gerçekleştirirken karşılaştığım tüm zorluklarla başa çıkabilirim.					
2) Bir öğretmen olarak, öğrencilerimin takdirlerini kazanabilirim.					
3) İşimden oldukça memnunum.					
4) Öğretimde, teknolojik gelişmelerin tüm kolaylıklarından faydalanabilirim.					
5) Sınıftaki anlaşmazlıkları ve kötü davranışları (şiddet, sataşma, yıkıcılık, vb…) yönetmede ve çözmede hızlı hareket edebilirim.					
6) İşimdeki başarılarımdan memnunum.					
7) Öğrencilerimin kurallara ve davranış ilkelerine saygı duymalarını ve uymalarını sağlayabilirim.					
8) En isteksiz ve zor öğrencileri bile sınıf aktivitelerine dâhil edebilirim.					
9) Beklenmedik veya zor görevlerle karşılaştığımda bile işimi organize eder ve tamamlayabilirim.					
10) Öğrencilerimin problemli davranışlarıyla etkili bir şekilde başa çıkabilirim.					
11) Okulda kendimi iyi hissederim.					
12) Bütün iş arkadaşlarımın güven ve takdirini kazanabilirim.					
13) Engelli öğrencilerin okul sistemine girdiklerinde karşılaştıkları tipik zorluklarla nasıl baş edileceğini bilirim.					
14) İş arkadaşlarımın ve yöneticilerimin bana karşı davranışlarından memnunum.					
15) Bir öğretmen olarak, yaptığım işlerle velilerin takdirlerini kazanabilirim.					
16) Okul yöneticilerinin güven ve takdirimi kazanabilirim.					

*3., 6., 11. and 14. items are constructed for job satisfaction, others for perceived self-efficacy.

APPENDIX F

APPROVAL OF METU HUMAN RESEARCHES ETHIC COMMITTEE

1956

Orta Doğu Teknik Üniversitesi
Middle East Technical University
Fen Bilimleri Enstitüsü
Graduate School of
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Fax: +90 (312) 2107959
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Sayı: B.30.2.ODT.0.AH.00.00/126/ 50 - 452

25 Mart 2011

Gönderilen: Yrd. Doç. Dr. Ömer Faruk Özdemir
Ortaöğretim Fen ve Matematik Alanları Eğitimi

Gönderen : Prof. Dr. Canan Özgen
IAK Başkan Yardımcısı

İlgi : Etik Onayı

"Ortaöğretim Kurumlarında Görev Yapan Fizik Öğretmenlerinin Elektrik Konusunun Öğretimine Yönelik Pedagojik Alan Bilgilerinin Ölçülmesi" isimli araştırmanız "İnsan Araştırmaları Komitesi" tarafından uygun görülerek gerekli onay verilmiştir.

Bilgilerinize saygılarımla sunarım.

Etik Komite Onayı

Uygundur

25/03/2011

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

APPENDIX G

PERMISSION OF THE TURKISH MINISTRY OF NATIONAL EDUCATION

ÖĞREN…
DAİRESİ BA…
Arş. Md Sı :

T.C.
MİLLÎ EĞİTİM BAKANLIĞI
Eğitimi Araştırma ve Geliştirme Dairesi Başkanlığı

Sayı : B.08.0.EGD.0.07.00.00.605.99-553/2670 14.../06/2011
Konu : Araştırma İzni

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE

İlgi : a) 18.05.2011 tarih ve B.30.2.ODT.72.00.00-2906/6018 sayılı yazı,
b) 31.05.2011 tarihli Araştırma Değerlendirme Komisyon Kararı,
c) 28.02.2007 tarih ve B.08.0.EGD.0.33.05.311-311/1084 sayılı Makam Onayı ile Uygulamaya Konulan "Millî Eğitim Bakanlığına Bağlı Okul ve Kurumlarda Yapılacak Araştırma ve Araştırma Desteğine Yönelik İzin ve Uygulama Yönergesi.

Üniversiteniz Ortaöğretim Fen ve Matematik Alanları Eğitimi Anabilim Dalı Doktora öğrencisi Eralp BAHÇIVAN'ın "Ortaöğretim Kurumlarında Görev Yapan Fizik Öğretmenlerinin Elektrik Konusunun Öğretimine Yönelik Pedagojik Alan Bilgilerinin Ölçülmesi" konulu araştırmasında kullanılacak veri toplama araçlarını Aksaray Hizmetiçi Eğitim Enstitüsünde gerçekleştirilecek olan 516 numaralı "Fizik Dersi Öğretim Programları (I. Kademe) Kursu" başlıklı faaliyete katılacak olan Fizik öğretmenlerine uygulama izni talebi incelenmiştir.

Üniversiteniz tarafından kabul edilerek onaylı bir örneği Bakanlığımızda muhafaza edilen 9 sayfa 15 sorudan oluşan veri toplama araçlarının Aksaray Hizmetiçi Eğitim Enstitüsünde gerçekleştirilecek olan 516 numaralı "Fizik Dersi Öğretim Programları (I. Kademe) Kursu" başlıklı faaliyete katılacak olan Fizik öğretmenlerine uygulanmasında bir sakınca görülmemektedir.

İlgi (c) Yönergenin 5. Maddesinin (o) bendi uyarınca teslim tutanağının imzalanarak araştırmanın bitiminde sonuç raporunun iki örneğinin Bakanlığımıza gönderilmesi gerekmektedir.

Bilgilerinizi ve gereğini rica ederim.

Murat YALÇIN
Bakan a.
Daire Başkanı

EK :
Veri Toplama Aracı (1 Adet-9 Sayfa)

17.06.11*010536

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APPENDIX H

RUBRIC

YÖNERGE

Değerlendirmeciler aşağıdaki kıstasları dikkate alarak puanlandırma yapmalıdırlar.

1. Katılımcıların kâğıtlarını değerlendirirken aşağıda görülen cevap anahtarını kullanınız.

2. Bu cevap anahtarı, katılımcıların kâğıdında yer alan ilk 10 ve 15. soru için kullanılacaktır. 11, 12, 13 ve 14. sorularla ilgili olarak herhangi bir değerlendirme yapmayınız.

3. Değerlendirmenizi yaparken bir soruyu bütün katılımcılar için değerlendirdikten sonra diğer sorulara geçiniz.

4. El yazısı, cümle yapısı gibi nicelikleri puanlandırmayınız.

5. Her soru için katılımcının cevap kâğıdında gördüğünüz ve cevap anahtarında yer alan maddeleri puanlandırınız. Her maddenin puanı o maddenin devamında parantez içerisinde verilmiştir.

6. Katılımcının cevabı cevap anahtarındaki maddelere birebir uymuyor ise cevaba en yakın olduğunu düşündüğünüz (eş anlamlı) maddeye gidiniz ve puanını en yakın maddeye göre veriniz.

7. 15. soruda puanlandırmayı aşağıdaki kıstaslara uygun olarak yapınız.

7.1. Katılımcının yazdığı her kavram yanılgısına 1 puan veriniz.

7.2. Çürütücü ifadeleri puanlandırırken cevap anahtarında belirtilen çürütücü ifadelerin puanlarını dikkate alınız. Her çürütücü ifadenin puanı, ifadenin devamında parantez içerisinde verilmiştir.

7.3. Katılımcı kavram yanılgısı yazmış ve kullandığı çürütücü ifade yanlış ise1 puan veriniz.

8. Yönergede belirtilen durumların dışında herhangi bir puanlandırma yapmayınız.

CEVAP ANAHTARI

1. Soru İçin Cevap Dağılımı

a) İletken bir cisimde yükün nasıl dağıldığını bilmiyorlar. (0,25)
b) Birbirine dokunan cisimlerde potansiyel eşitliği ilkesini bilmiyor veya uygulayamıyorlar. (0,25)
c) İçi boş iletkene başka bir iletken cismi içeriden dokundurmak ile bir iletken tel yardımıyla içeriye bağlanmak farklı şeylerdir. Öğrenciler bu durumu ayırt edemiyor ve X cismini içerden dokundurulmuş gibi düşünüyorlar. (1,50)

2. Soru İçin Cevap Dağılımı

a) Yükleri yalnızca yarıçaplara göre dağıtmayı biliyorlar. (0,25)
b) Dokunma ve etki ile elektriklenme olaylarını karıştırıyorlar. Etki ile elektriklenmenin cisimlerin yük cinsine etki edeceğini ancak cisimler birbirine dokunduğu için yük dağılımının dokunma ile elektriklenme kurallarına göre gerçekleşeceğini düşünüyorlar. (1,00)
c) Birbirine dokunan iletken cisimleri bir bütün olarak düşünemiyorlar. (0,25)
d) Yüklerin korunumu ilkesini ihmal ediyorlar. (0.25)
e) Çubuğun dokundurulduğunu yüklerin ise korunması gerektiğini düşünmüş olabilirler. (0.25)

3. Soru İçin Cevap Dağılımı

a) Elektron B noktasını geçtikten sonra kürenin sol tarafındaki (+) yükler tarafından daha büyük şiddetle çekilir, C noktasını geçtikten sonra ise kürenin sağ tarafındaki (+) yükler tarafından daha büyük şiddetle çekilir, dolayısıyla kürenin içinden geçerken önce yavaşlar sonra hızlanır şeklinde düşünüyorlar. (1,00)
b) İçi boş iletken kürenin iç yüzeyinin nötr olacağını ve içeride elektrik alan olmayacağı bilgisini bilmiyor veya uygulayamıyorlar. (0,50)
c) Elektriksel alanın olmadığı bir yerde yüklü bir cisme elektriksel kuvvet etki edemeyeceğini düşünemiyorlar. (0,50)

4. Soru İçin Cevap Dağılımı

a) Elektroskobun yapraklarının ve topuzunun birbirleriyle temas halinde olmalarından dolayı, bir bütünmüş gibi düşünerek, daima aynı cins yük barındırması gerektiğini düşünüyorlar. (1,00)
b) Etki ile elektriklenmede aynı işaretli yüklerin daima birbirinden en uzakta olan noktalarda toplanacağı bilgisini ihmal ediyorlar. (1,00)

5. Soru İçin Cevap Dağılımı

a) Topraktan elektron çekileceğini düşünemiyorlar ve topraklama da sadece (–) yüklerin toprağa aktığını düşünüyorlar. (0,50)
b) Önce toprağa yakın uçta (–) yüklerin, uzak uçta ise (+) yüklerin toplanacağını düşünüyorlar. Sonra da (–) yüklerin (+) yüklere göre toprağa daha yakın olmalarından dolayı nötrleneceğini düşünüyorlar. Bu durum toprak bağlantısının cismin alışılagelen tarafında değil ters tarafında olmasından oluyor. (0,75)
c) Bir cisim üzerinde topraklama ile yaratılacak etkinin, o cisme yaklaştırılan yüklü bir cismin etkisinden daha şiddetli olacağını ve yaklaştırılan yüklü cismin yerküre karşısında kendine yakın uçta (–) yük tutamayacağını düşünüyorlar. (0,75)

6. Soru İçin Cevap Dağılımı

a) Bir elektrik devresinde devre elemanlarının uçlarındaki potansiyeli bulamıyorlar. (0,50)
b) Elektrik devresinin temel bir devre görünümünde olmaması ve voltmetrenin karışık bağlanması uygulama hatası yapmalarına sebep oluyor. (0,25)
c) Voltmetrenin potansiyel farkı ölçtüğünü bilmiyorlar. Bundan dolayı Şekil II'deki voltmetrenin uçlarındaki potansiyelin hesaplanması gerektiğini düşünemiyorlar. (0,50)
d) Şekil I'deki voltmetrenin, paralel bağlı olduğu direncin potansiyel farkını değil potansiyelini ölçtüğünü düşünüyorlar. Aynı düşünce ile Şekil II'deki voltmetrenin hangi dirence paralel bağlı olduğunu bulmaya çalışıyorlar ve doğru cevabı bulamıyorlar. (0,75)

7. Soru İçin Cevap Dağılımı

a) Üretecin kutuplarının işaretini sistem üzerine taşıyamıyorlar. (0,25)
b) Elektrik alan ve yük işareti arasındaki ilişkiyi bilmiyorlar. Elektriksel kuvvetin yönünün sadece elektrik alanın yönüne bağlı olduğunu düşünüyorlar. (0,75)
c) Derste verilen örneklerde cevap hep sağa gider şeklinde oluyor. Bu durum öğrencinin de hep aynı cevabı verecek şekilde koşullanmasına sebep oluyor. (0,50)
d) Akımın yönünün pozitiften negatife doğru olduğunu biliyorlar ve elektronun da aynı yönde hareket edeceğini düşünüyorlar. (0,50)

8. Soru İçin Cevap Dağılımı

a) El feneri gibi düşünüyorlar ve ampulün yanacağı kararına varıyorlar. (0,75)
b) Ampulün de iki kutuplu olması gerektiğini göremiyorlar. İletken tel ile ampulün temasının, ampulden akım geçebilmesi için yeterli olduğunu düşünüyorlar. (0,50)
c) Direncin lamba şeklinde çizilmiş olması öğrencilerin kapalı devre oluşmadığını görmelerine engel oluyor. Lambanın da bir direnç olduğunu düşünemiyorlar. (0,75)

9. Soru İçin Cevap Dağılımı

a) Yukarıdaki iki lambanın aynı kolda görünüyor olmalarından dolayı potansiyeli iki eşit parça halinde paylaşacaklarını alttaki lambanın ise aynı potansiyeli tek başına kullanacağını düşünüyorlar. (0,75)
b) Akımın başlangıçta iki eşit parçaya ayrıldığını, daha sonra üst kolda tekrar iki eşit parçaya ayrıldığını düşünüyorlar. (0,75)
c) I_3 akımının aldığı yolun diğerlerinden daha uzun görünüyor olması bu akımın değerinin daha düşük olması gerektiğini düşünmelerine sebep oluyor. (0,50)

10. Soru İçin Cevap Dağılımı

a) Transformatörün çalışma prensibini bilmediklerinden, yüksek potansiyelin daima yüksek akım oluşturacağını ve $P = I^2R$ formülünden yola çıkarak daha fazla enerji kaybı olacağını düşünüyorlar. (1,00)
b) Yüksek gerilim denilince çok miktarda elektronun devreden geçeceğini bununda sürtünmeden dolayı enerji kaybını artıracağını düşünüyorlar. (0,75)
c) Gerilim ve akım kavramlarını karıştırıyorlar. (0,25)

15. Soru İçin Cevap Dağılımı

Kavram	Kavram Yanılgısı	Çürütücü İfade
Elektrik Akımı	Elektrik akımı elektronların akımıdır.	1) Elektronların akımı değil, elektronların birbirini etkilemesidir (titreşimidir). Elektrik akımı elektronların titreşimi yolu ile enerjinin iletilmesidir. (1,00)
	Elektrik akımını oluşturan elektronlar ışık hızı ile hareket eder.	1) Işık hızına yakın bir hızda yayılan, enerjidir. (0,50) 2) Elektronlar değil fotonlar ışık hızında hareket eder. (1,00)
	Akım, elektronların hareket yönü ile aynı yöndedir.	1) Elektrik akımı bir üretecin (+) kutbundan (–) kutbuna doğrudur. Elektronlar ise (–) kutuptan (+) kutba doğru hareket eder. (1,00)
	Akım, yüklerin ,(+) kutuptan (–) kutba doğru hareketi ile oluşur.	1) Akım, elektronların (–) kutuptan (+) kutba doğru hareketi ile oluşur. (0,50) 2) Akım, kapalı bir devrede potansiyel fark varsa yüksek potansiyelden düşük potansiyele doğru hareket eder. (1,00)
	Akım, bir pilin pozitif ve negatif kutbundan çıkıp ampulün üzerinde çarpışır.	1) Akım sadece (+) kutuptan (–) kutba doğru akar. (0,50) 2) Elektronlar sadece (–) kutuptan (+) kutba doğru titreşim halinde ilerler. Dolayısıyla akımın da tek yönü vardır ve elektron hareketine ters yöndedir. (1,00)
	Üreteç/pil içerisinde akım yoktur.	1) Üretecin de kendi iç direnci vardır ve üzerinden akım geçer. Üreteç üzerinden akım geçmezse, devre açık devre olur. (0,50) 2) Üzerinden akım geçen lamba ısınır. Üreteçler de bir süre sonra ısınır. Bu da üreteçlerin içinden akım geçtiğini gösterir. (1,00)
	Elektrik akımı iletken telin ucunda bekler.	1) İletken tel açık bir devrenin elemanı ise sadece telin ucundaki değil bütün devre elemanları içindeki elektronlar yerinde bekler ve devrede akım oluşmaz. (0,50) 2) Potansiyel fark olduğu sürece kapalı bir devrede elektrik akımı vardır. Potansiyel fark olmadığı anda ise akım beklemez yok olur. (1,00)
	Akım, pozitif yüklerin hareketi ile oluşur.	1) Pozitif yükler hareket etmez. (0,50) 2) Elektronlar (–) kutuptan (+) kutba doğru titreşimi iletirler, ancak bu titreşimin olması için devrede potansiyel fark olması

Elektrik Akımı		gerekir. (1,00)
	Elektrik akımı direnç üzerinde harcanır.	1) Akım yolu ile elektronlar tarafından taşınan elektriksel enerji devre elemanları üzerinde hareket, ısı, ışık ve/veya ses enerjisine dönüşür. Akıma neden olan elektronların sayısında bir değişim olmadığından akım da değişmez. (1,00)
	Elektrik akımının oluşabilmesi için potansiyel farkın değiştirilmesi gerekir.	1) Potansiyel farkın oluşabilmesi için devrede üreteç olması gerekir. Lambanın yanması için ise devrede üreteç olması yani potansiyel fark oluşturulması yeterlidir, üreteci devamlı değiştirmemize gerek yoktur. (1,00)
Potansiyel Fark	Potansiyel fark bir noktanın potansiyelidir.	1) Potansiyel fark, iki farklı noktanın potansiyelleri arasındaki farktır. (1,00)
	Bir elektrik devresinde potansiyel fark akar.	1) Potansiyel fark, akımın oluşmasını sağlar. (1,00) 2) Bir elektrik devresinde elektronlar titreşir ve enerji iletilir. (1,00)
	İki nokta arasında potansiyel fark oluşması için yüklerin zıt işaretli olması gerekir.	1) Yüklerin işaretlerinin bir önemi yoktur. (0,50) 2) Farklı iki noktanın potansiyellerin farklı olması gerekir. (1,00)
	Bir devrenin potansiyel farkının değiştirilebilmesi için devredeki akımın değiştirilmesi gerekir.	1) Devredeki potansiyel fark üreteç tarafından oluşturulur ve akımın değiştirilmesi ile değil ancak üretecin değiştirilmesi yoluyla değiştirilebilir. (1,00)
	Potansiyel fark vektörel bir büyüklüktür.	1) Potansiyel fark skaler bir büyüklüktür dolayısıyla yönü, doğrultusu, etki noktası yoktur. (1,00)
	Pil bittiğinde potansiyel fark sıfır olur.	1) Devreye bağlı olmayan ve bittiğini düşündüğümüz pilin uçlarına voltmetreyi bağladığımızda hala potansiyel fark olduğunu görürüz. (1,00)
	Potansiyel fark pilin gücüdür.	1) Gücün birimi watt, potansiyel farkın birimi volttur. (1,00) 2) Potansiyel fark, iki farklı noktanın potansiyelleri arasındaki farktır. Güç ise birim zamanda yapılan iştir. (0,50)
	Potansiyel fark ve potansiyel enerji aynı şeylerdir.	1) Potansiyel fark iki noktanın potansiyelleri arasındaki farktır, enerji değildir. (0,50) 2) Potansiyel farkın birimi volt, potansiyel enerjinin birimi ise

		jouledür. (1,00)
Elektrostatik Kuvvet	Elektrostatik kuvvet yoktur.	1) Elektrostatik kuvvet vardır ve Coulomb kanununa göre hesaplanır. (0,50) 2) Yünlü kumaşa sürtülen ebonit çubuğun (ya da ipek kumaşa sürtülen cam çubuğun / saça sürtülen tarağın) kâğıt parçalarını çekmesini sağlayan bu kuvvettir. (1,00)
	Durgun yük miktarı fazla olan cisim diğerine daha büyük kuvvetle etki eder.	1) Birbirlerine etkiyen cisimlerin uyguladıkları elektrostatik kuvvetlerin büyüklükleri aynı, yönleri ise birbirlerine zıttır. (0,50) 2) Coulomb kanununa göre cisimlerin üzerine etkiyen elektrostatik kuvvetin şiddeti her iki cismin de yük miktarları ile doğru orantılı ve eşit şiddettedir. (0,50) 3) Etki ve tepki kuvvetleri büyüklük olarak eşittir. (1,00)
	Yüklü bir cisim ile nötr cisim arasında etkileşim yoktur.	1) Yüklü cisim nötr cismin önce etki ile elektriklenmesini sağlar. Sonra nötr cismi kendine doğru çeker. (0,50) 2) Yünlü kumaşa sürtülen ebonit çubuk kâğıt parçalarını çeker. Kâğıt parçalarının nötr olması bu durumu değiştirmez. (1,00)
	Elektrik alan ve elektriksel kuvvet aynı yönlüdür.	1) Elektrik alan içindeki pozitif yüklere elektrik alan ile aynı yönlü negatif yüklere ise ters yönlü elektriksel kuvvet etki eder. (1,00) 2) Elektrik alan daima pozitiften negatife doğrudur. Elektriksel kuvvetin yönü ise hem elektrik alanın yönüne hem de yüklü cismin kendi yük işaretine göre değişir. (1,00)
	Elektriksel kuvvetle elektrik alan aynı şeylerdir.	1) Elektriksel alan içerisinde yük var ise o yüke elektriksel kuvvet etki eder. (0,50) 2) İkisi de vektörel büyüklüktür. Ancak elektrik alan içerisindeki yük negatif ise alan ile ters yönlü kuvvet etki eder. (1,00)

APPENDIX I

EXAMPLES OF RESPONSES

I.1 TEACHER A

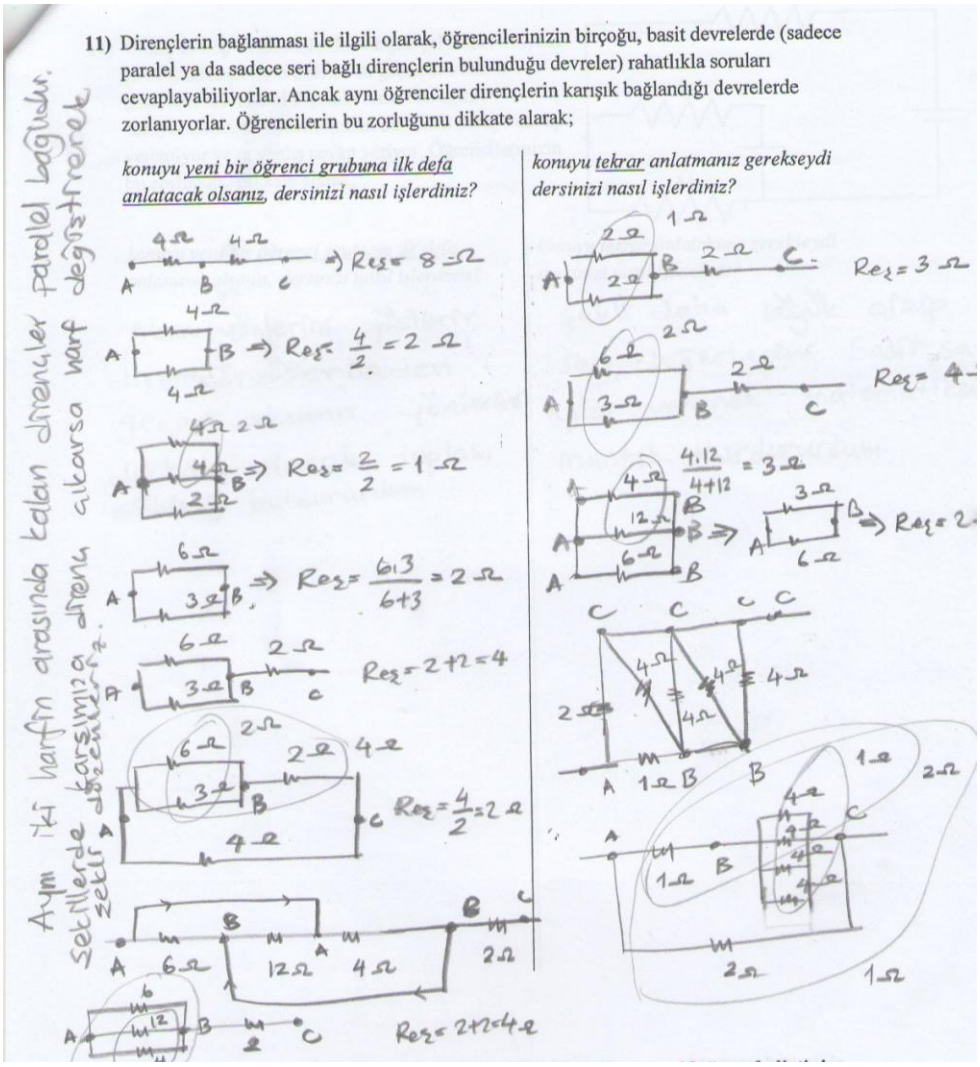
11) Dirençlerin bağlanması ile ilgili olarak, öğrencilerinizin birçoğu, basit devrelerde (sadece paralel ya da sadece seri bağlı dirençlerin bulunduğu devreler) rahatlıkla soruları cevaplayabiliyorlar. Ancak aynı öğrenciler dirençlerin karışık bağlandığı devrelerde zorlanıyorlar. Öğrencilerin bu zorluğunu dikkate alarak;

konuyu yeni bir öğrenci grubuna ilk defa anlatacak olsanız, dersinizi nasıl işlerdiniz?	*konuyu tekrar anlatmanız gerekseydi dersinizi nasıl işlerdiniz?*
- Öncelikle günlük hayatta yaşadıkları ortamları örnek vererek, evlerindeki lambaların nasıl yandığını sorarak farkları (odalarındaki) görmelerini sağlardım - Sınıfta basit devrelerin devrelerin içindeki ampul sayılarını arttırıp, bağlanma şekilleri ayrı ayrı denemelerini sağlayarak, parlaklıklarını kıyaslamalarını isterdim. - farklı soru şekillerini görebilme	- Yeni soru çeşitleriyle pekiştirirdim.

I.2 TEACHER B

11) Dirençlerin bağlanması ile ilgili olarak, öğrencilerinizin birçoğu, basit devrelerde (sadece paralel ya da sadece seri bağlı dirençlerin bulunduğu devreler) rahatlıkla soruları cevaplayabiliyorlar. Ancak aynı öğrenciler dirençlerin karışık bağlandığı devrelerde zorlanıyorlar. Öğrencilerin bu zorluğunu dikkate alarak;

konuyu <u>yeni bir öğrenci grubuna ilk defa anlatacak olsanız</u>, dersinizi nasıl işlerdiniz?	*konuyu <u>tekrar</u> anlatmanız gerekseydi dersinizi nasıl işlerdiniz?*
Öğrencileri laboratuvara indirir, 4-5 kişilik grupla-ra ayırırarak her bir gruba malzemeleri verip devre oluşturmalarını ister, oluştur-dukları devreleri sembollerle göstermelerini sağlardım. Daha sonra örnek bir bağlama yapara formülleri kullanarak bulduğumuz değer-lerle deney sonucu bulunan değerleri mukayese ettirir-dim.	Çocukları laboratuvara götürerek sol taraftaki işlemleri yapardım.

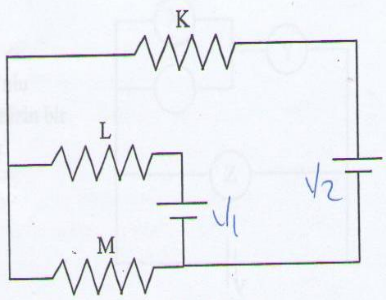


11) Dirençlerin bağlanması ile ilgili olarak, öğrencilerinizin birçoğu, basit devrelerde (sadece paralel ya da sadece seri bağlı dirençlerin bulunduğu devreler) rahatlıkla soruları cevaplayabiliyorlar. Ancak aynı öğrenciler dirençlerin karışık bağlandığı devrelerde zorlanıyorlar. Öğrencilerin bu zorluğunu dikkate alarak;

konuyu <u>yeni bir öğrenci grubuna ilk defa anlatacak olsanız</u>, dersinizi nasıl işlerdiniz?	konuyu <u>tekrar</u> anlatmanız gerekseydi dersinizi nasıl işlerdiniz?
$R_{eş} = 8\,\Omega$ $R_{eş} = \frac{4}{2} = 2\,\Omega$ $R_{eş} = \frac{2}{2} = 1\,\Omega$ $R_{eş} = \frac{6 \cdot 3}{6+3} = 2\,\Omega$ $R_{eş} = 2+2 = 4$ $R_{eş} = \frac{4}{2} = 2\,\Omega$ $R_{eş} = 2+2 = 4\,\Omega$	$R_{eş} = 3\,\Omega$ $R_{eş} = 4$ $\frac{4 \cdot 12}{4+12} = 3\,\Omega$ $R_{eş} = 2$

Aynı iki harfin arasında kalan dirençler paralel bağlıdır. Şekillerde karşımıza direnç çıkarsa harf değiştirerek şekil düzenlenir.

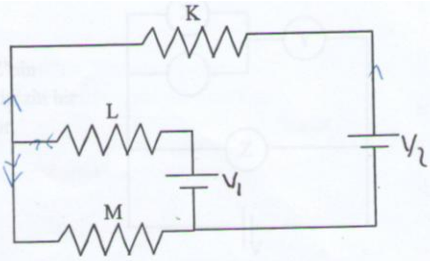
12) Özdeş üreteç ve dirençlerden oluşan şekildeki devrede K ve L dirençlerinin üzerinden geçen akımların şiddetleri arasındaki ilişkinin nasıl olacağını soruyorsunuz. Öğrencilerinizin bir kısmı soruya cevap veremiyor veya yanlış cevap veriyor. Öğrencilerinizin bu zorluğunu dikkate alarak;



konuyu <u>yeni bir öğrenci grubuna ilk defa</u> anlatacak olsanız, dersinizi nasıl işlerdiniz?	*konuyu <u>tekrar</u> anlatmanız gerekseydi dersinizi nasıl işlerdiniz?*
1) V_1 den çıkan akımın yolunu ve değerlerini 2) V_2 den çıkan akımın yolunu ve değerlerini anlatır. 3) Aynı yönde giden akımların toplanacağını zıt yönde giden akımların farkının alınacağını belirterek anlatırdım.	Voltmetre, Ampermetre ve Direnç ile Güç kaynağını kullanarak devreyi kurar. Devre üzerinde, şema üzerinde izah ederek veya bilgisayarda simülasyon yaparak akımın iletkenler de akışını göstererek anlatırdım.

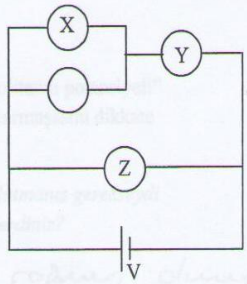
I.5 TEACHER E

12) Özdeş üreteç ve dirençlerden oluşan şekildeki devrede K ve L dirençlerinin üzerinden geçen akımların şiddetleri arasındaki ilişkinin nasıl olacağını soruyorsunuz. Öğrencilerinizin bir kısmı soruya cevap veremiyor veya yanlış cevap veriyor. Öğrencilerinizin bu zorluğunu dikkate alarak;

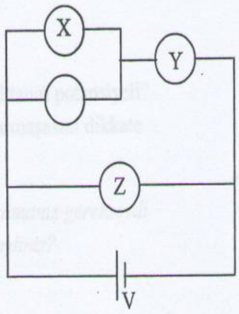


konuyu yeni bir öğrenci grubuna ilk defa anlatacak olsanız, dersinizi nasıl işlerdiniz?	*konuyu tekrar anlatmanız gerekseydi dersinizi nasıl işlerdiniz?*
Üreteçlerden çıkan akımların yönlerini değişik renkte kalemlerle ve mümkünse sayısal değerlerde vererek konuyu anlatırım.	Bir kaç örnek verirdim. Daha sonra buna benzer sorular öğrencilerimi gruplara ayırarak her gruba örneğe benzer fakat farklı sorular sorarak bir dahaki derse hazırlıklı gelmelerini ve kendi aralarında tartışmalarını çok önerirdim.

13) **Şekildeki devrede verilen özdeş lambalardan X, Y ve Z'nin parlaklıklarını sıralamalarını istiyorsunuz ve öğrencilerinizin bir kısmı soruya cevap veremiyor veya yanlış cevap veriyor. Öğrencilerinizin bu zorluğunu dikkate alarak;**



konuyu <u>yeni bir öğrenci grubuna ilk defa</u> anlatacak olsanız, dersinizi nasıl işlerdiniz?	*konuyu <u>tekrar</u> anlatmanız gerekseydi dersinizi nasıl işlerdiniz?*
Önceki öğrenci grubunun düştüğü kavram yanılgılarını tespit eder ve ona göre bir çözüm metni değiştir. Sonra konuyu tekrar anlatırdım. Ve örneklerle pekiştiririm. Öğrenci burada potansiyel farkının paralel ve seri devrede nasıl dağıldığını kavrayamamış, akım ve parlaklıklar ilişkisini kuramamış	aynısını yapardım yine olmazsa meslektaşlarımdan destek alırım(!)



13) **Şekildeki devrede verilen özdeş lambalardan X, Y ve Z'nin parlaklıklarını sıralamalarını istiyorsunuz ve öğrencilerinizin bir kısmı soruya cevap veremiyor veya yanlış cevap veriyor. Öğrencilerinizin bu zorluğunu dikkate alarak;**

konuyu yeni bir öğrenci grubuna ilk defa anlatacak olsanız, dersinizi nasıl işlerdiniz?

Parlaklıklar güçle ilgilidir. Özdeş lambalarda $\alpha\left(\frac{V^2}{R}\right)$ yada $(i^2 R)$ parlaklığı en fazla olanın voltaj değerinin en büyük olduğu söylenir. Devre üzerinde voltaj değerleri bulunarak sıralama yapılır. Parlaklıkların da aynı şekilde sıralandığı gösterilir.

Bu şekilde deney düzeneği de kurulup gösterilir.

konuyu tekrar anlatmanız gerekseydi dersinizi nasıl işlerdiniz?

Rakamlarla örnek yapardım. Şekil üzerinde voltaj değerlerini bulup, parlaklıkların da buna göre sıralanacağı anlatılır. Her lambanın gücünü hesaplayarak, parlaklık – güç ilişkisini görmeleri sağlanır.

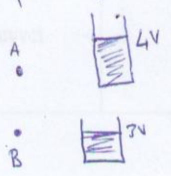
14) **Ders esnasında öğrencilerinizin bir kısmının "potansiyel fark" ve "noktanın potansiyeli" kavramlarını karıştırdığını fark ettiniz. Öğrencilerinizin bu kavram karmaşasını dikkate alarak;**

konuyu yeni bir öğrenci grubuna ilk defa anlatacak olsanız, dersinizi nasıl işlerdiniz?	***konuyu tekrar anlatmanız gerekseydi dersinizi nasıl işlerdiniz?***
Aşağıdaki gibi bardak ve su örnekleri ile açıklamaya çalışırım.	

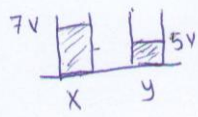
Bir noktanın potansiyeli

A noktası için

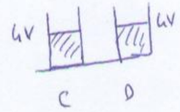
B noktası için



Potansiyel farkı



X ve y'nin potansiyel farkı 2V gibi



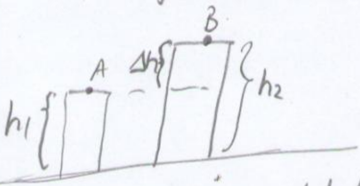
C ve D'nin potansiyelleri eşit yani potansiyel farkı sıfırdır. gibi

I.9 TEACHER I

14) Ders esnasında öğrencilerinizin bir kısmının "potansiyel fark" ve "noktanın potansiyeli" kavramlarını karıştırdığını fark ettiniz. Öğrencilerinizin bu kavram karmaşasını dikkate alarak;

konuyu yeni bir öğrenci grubuna ilk defa anlatacak olsanız, dersinizi nasıl işlerdiniz?	*konuyu tekrar anlatmanız gerekseydi dersinizi nasıl işlerdiniz?*

Her iki durumda da olayın mekanik teki benzeri-
ni gösterirdim.
Potansiyelin yere göre yükseklik, pot. farkının ise
~~ty~~ iki noktanın yere göre yükseklik farkı gibi
düşünüleceğini ifade ederim.



h_1 ve h_2 → Noktaların potansiyeli
Δh → Pot. farkı

I.10 TEACHER J

14) Ders esnasında öğrencilerinizin bir kısmının "potansiyel fark" ve "noktanın potansiyeli" kavramlarını karıştırdığını fark ettiniz. Öğrencilerinizin bu kavram karmaşasını dikkate alarak;

konuyu yeni bir öğrenci grubuna ilk defa anlatacak olsanız, dersinizi nasıl işlerdiniz?	*konuyu tekrar anlatmanız gerekseydi dersinizi nasıl işlerdiniz?*
Öncelikle potansiyel kavramını noktanın potansiyelinden başlayarak daha sonra potansiyel fark'a girer ve pekişmesini sağlardım.	Kavramların karışmaması için noktanın potansiyelini ve potansiyel fark kavramlarını, tekrar hatırlattıktan sonra birbirinden farkını pekiştirmeye çalışırım.

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