INVESTIGATING PERCEPTIONS OF PRESERVICE MATHEMATICS TEACHERS ON THEIR TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK) REGARDING GEOMETRY

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ABSTRACT

INVESTIGATING PERCEPTIONS OF PRESERVICE MATHEMATICS TEACHERS ON THEIR TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK) REGARDING GEOMETRY

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The aim of this study is to investigate perceptions of preservice mathematics teachers' technological pedagogical content knowledge (TPACK) regarding geometry. In addition, the purpose is to examine the relationships among the components of TPACK. Moreover, possible gender and year of enrollment differences related to preservice mathematics teachers' technological pedagogical content knowledge dimensions are examined.

This research study has been conducted with 780 preservice mathematics teachers who are enrolled in elementary mathematics education department of Education Faculties of seven public universities located in Central Anatolia.

Perceived TPACK regarding geometry instrument has been developed to collect data. In order to determine the levels of preservice mathematics teachers' perceptions related to TPACK in geometry, descriptive information have been used. The results indicate that preservice mathematics teachers' perceptions of TPACK related to geometry is higher than moderate.

Furthermore, correlational analysis was conducted to identify the relationship among dimensions of TPACK. Positive significant correlations among the components of the TPACK framework were found in correlational analysis.

Besides, two-way MANOVA has been conducted to investigate a possible relationship between demographic information of preservice elementary mathematics teachers and their perceptions of TPACK. According to the MANOVA results, there are statistically significant differences between male and female preservice mathematics teachers in favor of male participants in three components of TPACK, namely technological knowledge, technological pedagogical knowledge and technological pedagogical content knowledge in favour of males.

Keywords: Technological Pedagogical Content Knowledge, Geometry, Preservice Mathematics Teachers, Gender, Elementary Mathematics Teacher Education

ÖZ

İLKÖĞRETİM MATEMATİK ÖĞRETMEN ADAYLARININ GEOMETRİ KONUSU İLE İLGİLİ ALGILADIKLARI TEKNOLOJİK PEDAGOJİK ALAN BİLGİLERİNİN ARAŞTIRILMASI

Bulut, Aykut

Yüksek Lisans, İlköğretim Fen ve Matematik Alanları Eğitimi

Tez Yöneticisi: Doç. Dr. Mine Işıksal

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Bu çalışmanın amacı ilköğretim matematik öğretmen adaylarının geometri konusuyla ilgili algıladıkları Teknolojik Pedagojik Alan Bilgilerini (TPAB) araştırmaktır. Çalışmanın diğer bir amacı ise Teknolojik Pedagojik Alan Bilgisi Modeli'nin alt boyutları arasındaki ilişkiyi araştırmaktır. Ayrıca bu çalışmada öğretmen adaylarının cinsiyet ve sınıf farklılıkları ile Teknolojik Pedagojik Alan Bilgisi Modeli'nin alt boyutları arasındaki ilişki incelenmiştir.

Bu çalışma İç Anadolu Bölgesi'nde yer alan yedi adet devlet üniversitesinin ilköğretim matematik eğitimi bölümünde eğitim gören 780 ilköğretim matematik öğretmen adaylarıyla yapılmıştır. Çalışmada veri toplamak amacıyla öğretmen adaylarının geometri ile ilgili algıladıkları teknolojik pedagojik alan bilgilerini ölçen anket geliştirilmiştir. İlköğretim matematik öğretmen adayılarının algıladıkları teknolojik pedagojik alan bilgilerinin seviyesini belirlemek için bazı betimleyici bilgiler kullanılmıştır. Çalışma sonuçlarına göre ilköğretim matematik öğretmen adaylarının geometri ile ilgili algıladıkları teknolojik pedagojik alan bilgileri ortalamanın biraz üstündedir.

Ayrıca, Teknolojik Pedagojik Alan Bilgisi Modeli'nin bileşenleri arasındaki ilişkiyi ortaya çıkarmak korelasyonal analiz kullanılmıştır. Bileşenler arasında da pozitif anlamlı bir ilişki bulunmuştur.

Ayrıca ilköğretim matematik öğretmen adaylarının demografik bilgileri ile Teknolojik Pedagojik Alan Bilgisi Modeli'nin bileşenleri arasındaki ilişkiyi araştırmak için iki yönlü MANOVA analizi kullanılmıştır. MANOVA sonuçlarına göre, teknolojik alan bilgisi, teknolojik pedagojik bilgi ve teknolojik pedagojik alan bilgisi ortalamaları erkek öğretmen adayları lehine anlamlı farklılık göstermektedir.

Anahtar Kelimeler: Teknolojik Pedagogik Alan Bilgisi, Geometri, İlköğretim Matematik Öğretmen adayları, Cinsiyet, İlköğretim Matematik Eğitimi

To My Family

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I dedicate this study to all members of my family, especially my mother and my father. I always feel their endless support and love which gives me perseverance to conduct this study. I know that they were with me when I needed. I would also like to thank my sister, my brother and my sister in law for their support and academic contributions about this study. I always felt their support next to me, and I always feel lucky to have such a family.

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CBMS: Conference Board of Mathematical Sciences

CK: Content Knowledge

DGEs: Dynamic Geometry Environments

ISTE: International Society for Technology in Education

KCS: Knowledge of Content and Students

MANOVA: Multivariate Analysis of Variances

MoNE: Ministry of National Education

NCTM: The National Council of Teachers of Mathematics

OECD: Organization for Economic Cooperation and Development

PCA: Principal Components Analysis

PCK: Pedagogical Content Knowledge

PISA: Programme for International Student Assessment

PK: Pedagogical Knowledge

SD: Standard Deviation

TCK: Technological Content Knowledge

TIMSS: Trends in International Mathematics and Science Study

TK: Technological Knowledge

TPACK: Technological Pedagogical Content Knowledge

TPK: Technological Pedagogical Knowledge

CHAPTER I

INTRODUCTION

Teaching mathematics needs well-prepared teachers in terms of different kinds of knowledge because of its complex structure (The National Council of Teachers of Mathematics [NCTM], 2000). Ball, Lubienski, and Mewborn (2001) suggest that teaching new content, using new curriculum materials, managing the challenges of change, enacting new practices depend on teachers' knowledge of mathematics. Moreover, Shulman (1987) states that teaching requires basic skills, content knowledge, and general pedagogical skills. Berry (2002) also defines teaching requirements and properties of well-prepared or high-qualified teachers in the same direction. These qualified teachers know not only the subject matter, but also how to organize and teach their lesson in order to help students to learn more easily. In addition, they know how and why their students learn. Thus, teachers' knowledge is an important issue to build up and enhance students' learning (NCTM, 2000).

The knowledge of teacher has made progress for decades through various studies such as Ball (1990a; 1990b; 2000), Borko, Eisenhart, Brown, Underhill, Jones, & Agard (1992), Grossman (1990), Hill, Ball, and Schilling (2008), Shulman (1986, 1987), Tamir (1988). Most of those research studies on teacher knowledge have focused on their knowledge structures such as their subject matter knowledge and their general pedagogical knowledge. Shulman (1986) divides teachers' content knowledge into three categories, namely subject matter knowledge, pedagogical content knowledge (PCK), and curricular knowledge. Furthermore, Shulman (1986) states that subject matter knowledge or content knowledge is a teachers' knowledge that can be used to understand the structures of subject matter. Curricular knowledge is the knowledge of the full range of programs that are designed for teaching a particular subject. Moreover, Shulman and his colleagues have proposed a special kind of teacher knowledge, pedagogical content knowledge (PCK) which has been generated by linking content knowledge and pedagogical knowledge. Figure related to the pedagogical knowledge, content knowledge and PCK is given below.

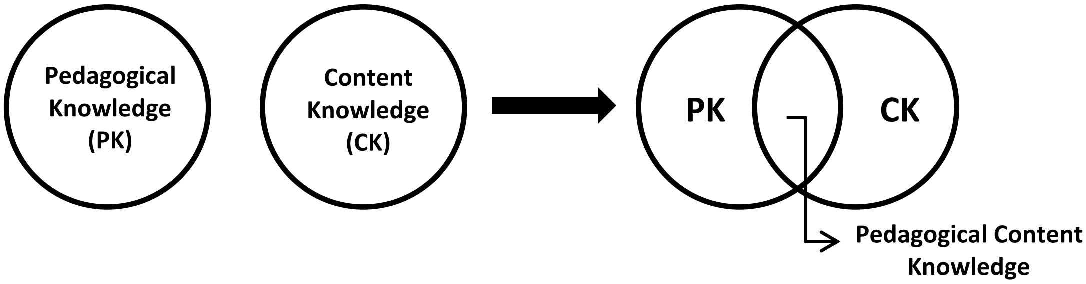

Figure 1 Pedagogical Content Knowledge Procedure, adapted from Mishra and Koehler (2006, p. 1022)

PCK is a unique kind of knowledge, since it intertwines content with aspects of teaching and learning (Ball et. al, 2001). Although technology and its relationship to pedagogy and content in terms of teacher knowledge were not discussed until 1990s, technology has existed since the beginning of human being, and it has been affected by different culture, religion and people (Aksoy, 2003). At present time, technology has been used in almost all areas of life. Thus, this evolution has affected education as well and the educational system has changed since the 1990s because technologies have come to the forefront of education (Mishra & Koehler, 2006). In accordance with this situation, NCTM (2000) states six principles and standards for school mathematics, and technology is one of these principles, since technology is a necessity in teaching and learning mathematics.

Teachers have potential to change education by using technology (Carr, Jonassen, Marra, & Litzinger, 1998), and the groundwork of teachers' knowledge about the educational uses of technology is a key component to improve education (Conference Board of Mathematical Sciences [CBMS], 2001; International Society for Technology in Education [ISTE], 2007). Moreover, the standards of NCTM (2000) are consistent with CBMS and ISTE in that teachers play important roles in technology integration, since the efficiency of using technology in mathematics classroom is directly related to the knowledge and technological skills of mathematics teachers. However, teachers should decide when and how technology will be used in instruction effectively. In other words, technology is not a cure-all medicine. Teachers should use it beneficially in order to enhance their students' learning regarding mathematics (NCTM, 2000). Similarly, as suggested by Dunham and Dick (1994), Rojano (1996), Sheets (1993) when appropriate technological tools are used in mathematics, students can learn more deeply (Dunham & Dick, 1994; Rojano, 1996; Sheets, 1993). NCTM (2000) state that teachers play a central role in students' learning; therefore, teachers must keep up with the ongoing technological developments. In brief, the need for integrating the technology to the knowledge of teachers is essential, and teachers should be sophisticated about not only pedagogy and content but also technology (Mishra & Koehler, 2006).

In the last few decades, with the increasing degree of importance of technology in education, a new dimension (technology) has been added to Shulman's (1986) model of PCK (see Figure 1) by Kohler and Mishra (2006). It means that technological pedagogical content knowledge (TPCK or TPACK) framework (see Figure 2) has been generated.

This framework has been generated to understand the teacher knowledge when technology is integrated in the classroom. This framework includes complex interplays between technology, content, and pedagogy. The results of interplays lead to seven different subsets: Technological Knowledge (TK), Pedagogical Knowledge (PK) and Content Knowledge (CK), Technological Content Knowledge (TCK) which is intersection of TK and CK; Technological Pedagogical Knowledge (TPK) which takes place at the intersection of TK and PK; Pedagogical Content Knowledge (PCK) is the intersection of PK and CK; and the last subset is the intersection of three main parts (TK, PK, CK); Technological Pedagogical Content Knowledge (TPCK). All parts of the framework have been explained in detail in the literature part.

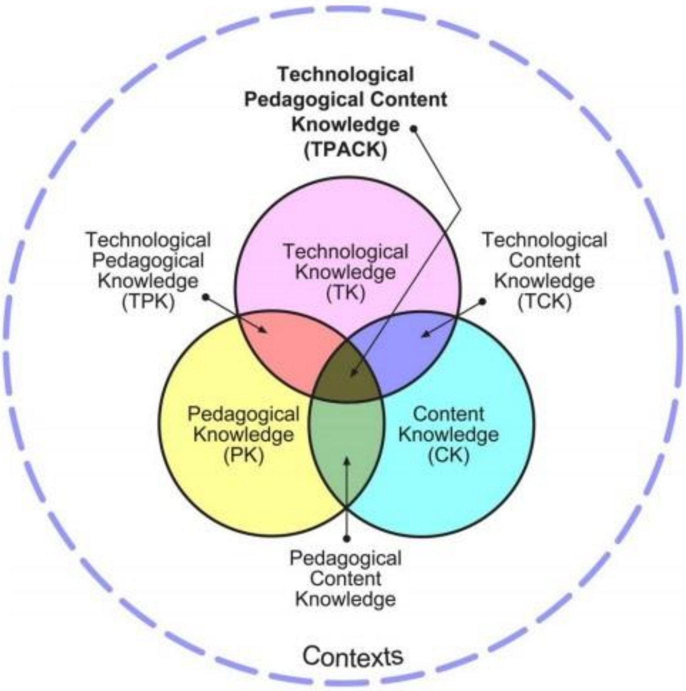

Figure 2 Technological Pedagogical Content Knowledge Framework, adapted from Koehler and Mishra (2009, p. 63)

1.1 Geometry and TPACK

Geometry is one of the essential parts of school mathematics and mathematics curriculum. Furthermore, it is also essential for students to succeed in their further studies in mathematics (NCTM, 2000). Battista (2007) states that geometry consists of complex interconnected concepts, ways of reasoning, and representation systems. Although geometry is an important area in mathematics and its application, students continue to have difficulty in order to learn geometry (Battista, 2007). By using technology, and computer software, students can understand the shapes and their properties, apply geometric properties to real world situations, and solve relevant problems in mathematics and other disciplines, so using technology helps teaching and learning of geometry (Kilpatrick, Swafford, & Findell, 2001; NCTM, 2000). In addition, if technology is used appropriately, students' geometric understanding and intuition can be affected positively. Therefore, computer environments could be ideal for teaching and learning geometry (Battista, 2007; Clements & Battista, 1992; NCTM, 2000).

In geometry, students can understand the basic concepts, explore conjectures, generate many examples, and discover the characteristics of geometric objects or shapes with the help of technological tools (NCTM, 2000) such as dynamic geometry software. Laborde, Kynigos, Hollebrands and Strässer (2006) state that mathematics technology is used in the teaching of geometry through the use of dynamic geometry software. Dynamic Geometry Environments (DGEs), which consist of dynamic geometry software, create dynamic and productive interactions between teacher, students, and computers in order to support the teaching and learning of geometry (Battista, 2001; Hativa, 1984; Hoffer, 1983). Sanders (1998) also says that using these software in classroom is a powerful teaching and learning method. Furthermore, it enhances mathematics teaching, helps with conceptual development, enriches visualization of geometry, and creates opportunities for creative thinking. In this regard, in the present research study, which aims to explore perceptions of preservice mathematics teachers in the area of geometry, geometry is considered as the content knowledge of the model suggested by Mishra and Koehler (2006), and knowledge and use of DGEs as technological content knowledge.

1.2 Significance of the Study

According to NCTM principles (2000), mathematics teachers must continue to learn new or additional content, analyze issues in teaching mathematics, study how students learn mathematics, and use new materials and technology. The effective use of technology in the mathematics classroom depends on the teacher, therefore, the appropriate technological tools that support instructional goals must be selected carefully (CBMS, 2001; NCTM, 2000; ISTE, 2007). In order to educate mathematics teacher related to technology integration in their classes, teacher preparation programs need to be well prepared. In other words, teacher preparation programs should provide assistance to preservice teachers in terms of using technology in instruction (Keating & Evans, 2001). From this point of view, the results of the present study may contribute to teacher preparation programs in terms of measuring perceptions of preservice mathematics teachers' TPACK related to geometry.

In recent years, the numbers of technologically equipped schools have increased in Turkey. This condition leads to increase the importance of technology knowledge. To exemplify, Turkish Ministry of National Education (MoNE) has attempted to integrate technology at schools. There are many projects held by MoNE to improve the schools technologically such as FATİH, e-okul, e-etüt (EGİTEK, 2011). However, integrating technology is not just adding technological knowledge in curriculum; it needs a complex mixture of technology, pedagogy and content knowledge (Koehler & Mishra, 2009). In other words, in order to integrate technology in education, teachers should have adequate technological pedagogical content knowledge (Mishra & Koehler, 2006). For these reasons, the aim of the present study is to find out perception levels of preservice mathematics teachers' technological pedagogical content knowledge and sub dimensions of TPACK framework. The results of this study could be used to determine whether preservice mathematics teachers feel themselves competent enough to integrate technology in geometry.

In contrast with the importance of technology in education, it does not seem to be enough studies related to the technology, pedagogy, and content knowledge of teachers, especially in Turkey. As mentioned earlier, TPACK has been studied in the last few decades. Therefore, the findings of the study are hoped to contribute to the field. To state differently, results of the present study would give information regarding how preservice mathematics teachers perceive TPACK and its dimensions, and relationships among TPACK components.

Since geometry is major field in mathematics, teachers should be well-educated and capable of teaching, and have adequate knowledge of geometry in order to integrate technology into teaching effectively (Battista, 2001; NCTM, 2000). Although some studies (Bal, 2012; Duatepe, 2000; Halat, 2008) show that Turkish preservice mathematics teachers' levels of geometry knowledge are moderate, the international test results indicate that achievement levels of geometry in Turkey is low. As an example, Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) have shown that the mathematics achievement levels of Turkish students, especially their geometry levels, are lower than the international average (Mullis, Martin, Gonzales, Gregory, Garden, O'Connor, Chrostowski, & Smith, 2000; Organization for Economic Cooperation and Development [OECD], 2004). In addition, in TIMSS (1999), Turkey ranked 34th among 38 countries in terms of geometry achievement (Mullis, et al., 2000). In order to increase students' achievement levels, integrating technology in geometry education can be considered as an alternative method. As stated above, using technology efficiently in mathematics classroom depends on mathematics teachers, especially their knowledge (NCTM, 2000). Therefore, examining teachers' technological knowledge in geometry is significant. For these reasons, geometry has been considered in design stage of this study, and geometry is selected as content knowledge in the TPACK framework.

Today's preservice mathematics teachers constitute the population of the future mathematics teachers, and they will use those technologies in their potential classrooms. For this reason, preservice teachers' TPACK are important in order to apply technology in classrooms in the future. Hence, this study attempts to illuminate the levels of preservice mathematics teachers on TPACK related to the geometry.

Demographic information of preservice mathematics teachers has been an issue of researchers' concern in terms of TPACK studies (e.g., Canbolat, 2011; Erdoğan & Şahin, 2010; Koh, Chai, & Tsai, 2010). Therefore, possible diversities regarding demographic information, especially gender differences and year of enrollment, on perceptions of preservice mathematics teachers on their TPACK regarding geometry have been examined in the present study.

1.3 Research Questions and Hypotheses

The following are the main research questions of the present study:

1. What are the levels of preservice mathematics teachers' perceptions on their TPACK in the field of geometry?

2. What are the relationships among perceptions of preservice mathematics teachers' content knowledge, pedagogical knowledge, technological knowledge, pedagogical content knowledge, technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge?

3. Is there a significant mean difference in perceptions of Turkish preservice elementary mathematics teachers' technological pedagogical content knowledge regarding geometry in terms of gender and year of enrollment?

   H_0: There is no significant mean difference between perceptions of Turkish female and male preservice elementary mathematics teachers' technological pedagogical content knowledge regarding geometry.

H_0: There is no significant mean difference between perceptions of junior and senior elementary mathematics students' technological pedagogical content knowledge regarding geometry.

1.4 Definition of Terms

Perceptions on TPACK: Perception is defined as the way you think about something and your idea of what it is like (Longman, 2012). In this study, perceptions on TPACK refer to how preservice mathematics teachers perceive technological pedagogical content knowledge and its dimensions.

Preservice mathematics teachers: Preservice mathematics teachers refer to juniors and seniors who are enrolled in elementary mathematics education undergraduate programs in the faculties of education which are located in Central Anatolia region in Turkey.

Technological Knowledge (TK): Technological knowledge is the knowledge about technologies which range from standard technologies such as pencil, paper to more advanced technologies such as Internet, interactive whiteboards (Schmidt, et al., 2009a). In this study, it refers to preservice teachers' knowledge about computer technologies, and properties of these technologies, and it is measured by technological knowledge dimension of perceived TPACK regarding geometry instrument.

Content Knowledge (CK): Content knowledge is "teachers' knowledge about the subject matter to be learned or taught" (Koehler & Mishra, 2009, p. 63). It is located in the mind of teacher (Shulman, 1986). In this study, it refers to preservice mathematics teachers' knowledge of geometry. It also includes knowledge of major facts and concepts in geometry. Content knowledge is measured by content knowledge dimension of perceived TPACK regarding geometry instrument.

Pedagogical Knowledge (PK): Pedagogical knowledge is "teachers' deep knowledge about the processes and practices or methods of teaching and learning" (Koehler & Mishra, 2009, p. 64). In this study, it refers knowledge of preservice mathematics teachers related to strategies and methods of teaching and learning. Moreover, it includes knowledge in classroom management, assessment, lesson plan development, and student learning. This dimension is assessed by pedagogical knowledge dimension of perceived TPACK regarding geometry instrument.

Pedagogical Content Knowledge (PCK): Pedagogical content knowledge is the intersection of content knowledge and pedagogy knowledge (Shulman, 1986). In this study, it refers to preservice teachers' pedagogical knowledge about the subject of geometry. It is assessed by pedagogical content knowledge dimension of perceived TPACK regarding geometry instrument.

Technological Content Knowledge (TCK): Technological content knowledge is "the knowledge of how technology can create new representations for specific content" (Schmidt, Baran, Thompson, Mishra, Koehler, Shin, 2009a, p. 125). In this study, technological content knowledge is preservice teachers' knowledge concerning geometry technologies, such as dynamic geometry software, and it is measured by technological content knowledge dimension of perceived TPACK regarding geometry instrument.

Technological Pedagogical Knowledge (TPK): Technological pedagogical knowledge is the intersection part of technological knowledge and pedagogical knowledge (Mishra & Koehler, 2006). In this study, it refers to the knowledge of how teaching and learning can change when teachers use various technologies in particular ways, and it is measured by technological pedagogical knowledge dimension of perceived TPACK regarding geometry instrument.

Technological Pedagogical Content Knowledge (TPACK): Technological pedagogical content knowledge is the knowledge of any topic, which is taught with good pedagogy by using appropriate technological tools (Koehler & Mishra, 2005). It means that TPACK is the interconnection and intersection of three knowledge types: content, pedagogy, and technology (McCormick &Thomann, 2007; Mishra & Koehler, 2006; Niess, 2005).

In the view of these descriptions, TPACK refers to preservice mathematics teachers' knowledge regarding the interrelationship between content (mathematics), pedagogy (teaching and student learning), and technology (dynamic software's of geometry). In this study, it is assessed by technological pedagogical content knowledge dimension of perceived TPACK regarding geometry instrument.

CHAPTER II

LITERATURE REVIEW

The purpose of this study is to investigate perceptions of preservice mathematics teachers' technological pedagogical content knowledge regarding geometry, and to explore some possible differences caused by the demographic profile dimensions related to preservice mathematics teachers' technological pedagogical content knowledge. The underlying theories are based on teachers' TPACK integrated in the conceptual framework of the present study. Theoretical background of the framework, and relevant studies have been referred to throughout the chapter. This chapter starts from the detailed explanation of Shulman's PCK to elaboration of Koehler and Mishra's TPACK. Then, the chapter continues with the previous studies related to the TPACK. Lastly, demographic differences in TPACK are explained, and the chapter concludes with a summary of the related studies in the literature.

2.1 Knowledge Frameworks

In this part, theoretical background of teachers' knowledge has been explicated. One of the aims of this research study is to investigate the relationship between preservice mathematics teachers' TPACK components. Thus, firstly background of the teacher's knowledge framework has been explained. Then, the translation processes of PCK to TPACK and TPACK frameworks have been mentioned. Since

Shulman's PCK model provides a basis of the TPACK frameworks, the priority has been given to Shulman's framework. After that, the other knowledge models, which are the extensions of Shulman's model, and the structures of technology attached to teachers' knowledge model have been explained.

2.1.1 Shulman's Framework of Teacher Knowledge

The knowledge, which is required for teachers, has been changing throughout the history of teacher education. Shulman (1986) stated that there was a sharp distinction between pedagogy and content in old times. By the late 1800s, pedagogy was lacking, or by the mid-1980s, content was ignored. However, in 1986, Shulman proposed a construct which was named as pedagogical content knowledge (PCK). In this construct, Shulman proposes a relationship between teacher's pedagogical knowledge and content knowledge. He states that there is integration between the two components and their intersection constitutes teacher's pedagogical content knowledge. Also, he mentions three knowledge types in his study: (a) subject matter content knowledge, (b) pedagogical content knowledge, and (c) curricular knowledge.

Subject matter knowledge or content knowledge is "the amount and organization of knowledge per se in the mind of teacher" (Shulman, 1986, p. 9). In order to understand subject matter knowledge, Shulman (1986) divides it in two structures; substantive and syntactic. The substantive structure includes some basic concepts and principles of the discipline. The syntactic structure includes truth or falsehood, validity or invalidity. According to Shulman (1986), a teacher, who has subject matter knowledge, must not only be capable of defining truths of a domain, but also be able to explain why it is true and worth knowing, and how it relates to other domains.

Curriculum is the full range of programs, and it is designed for teaching particular subjects or topics at a given level. Moreover, it includes a variety of instructional materials of these subjects (Shulman, 1986). Thus, curricular knowledge is the knowledge of programs and instructional materials about particular subjects or topics at a given level.

The other kind of teacher knowledge is pedagogical content knowledge. The definition of Shulman's (1987) PCK includes

> for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations- in a word, the ways of representing and formulating the subject that make it comprehensible to others… Pedagogical content knowledge also includes an understanding of what makes learning of specific topics easy or difficult… (p. 9).

In other words, PCK is both a special blending of content and pedagogy, and a unique province of teachers (Shulman, 1987). The model of Shulman's PCK can be seen in Figure 1. Shulman's framework and his proposal of PCK have been studied by many researchers by using different methodologies in different educational fields since its formation such as Ball (1990a; 1990b; 2000), Borko, Eisenhart, Brown, Underhill, Jones, and Agard (1992), Grossman (1990), Hill, Ball, and Schilling (2008), and Tamir (1988).

2.1.2 Grosmann's Framework of Teacher Knowledge

After Shulman's study, Grossman (1990) studied PCK based on Shulman's model. In 1990, Grossman separated PCK into four different areas: (a) knowledge and beliefs, (b) subject matter knowledge, (c) curricular knowledge, and (d) pedagogical content knowledge.

Grossman (1990) states that the first component refers to knowledge and beliefs about the purposes for teaching a subject at different grades. It includes teachers' beliefs about importance of subject for students, and teachers' purposes for teaching the content.

According to Grossman (1990), the second component, subject matter knowledge, is about understanding the major facts and concepts of the specific field. Knowledge of students' understanding, conceptions, and misconceptions of particular topics have been included in this component.

The third component suggested by Grossman (1990), curricular knowledge, has been defined in the same way as Shulman's approach. It refers to an understanding of the available materials for teaching a subject and knowledge about curricula for subject. Understanding the curriculum of a given subject and awareness of the overall educational objectives at a given level also take part in curricular knowledge.

The final component, pedagogical content knowledge, described by Grossman is the knowledge of instructional strategies and representations for teaching specific subjects. In this description Grossman (1990) states that "experienced teachers may possess rich repertoires of metaphors, experiments, activities, or explanations that are particularly effective for teaching a particular topic" (p. 9). Based on such a statement, Grossman emphasizes the importance of repertoires of multiple representations in PCK (Cox, 2008). However, Shulman (1987) states that PCK is not just a repertoire of multiple representations of the subject matter; it is also the development of pedagogical reasoning. In other words, Grossman's teacher knowledge and Shulman's teacher knowledge are different in terms of the meaning of PCK and the component of belief.

2.1.3 Ball et al.'s Framework of Mathematics Teachers' Knowledge

Shulman's (1986) and Grossman's (1990) frameworks are related to teachers' knowledge. To put it differently, they were general, not subject specific. However, Ball and his colleagues have studied with mathematics teachers, and suggested a framework related to mathematics teachers' knowledge.

Ball et al. (2008) name their model as mathematical knowledge for teaching. They propose that mathematical knowledge for teaching consist of two dimensions; subject matter knowledge and pedagogical content knowledge (see Figure 3). The subject matter knowledge is divided into two dimensions. Common content knowledge is defined as mathematical knowledge and skills is used in a wide variety of settings, so it is not unique for teaching. On the other hand, specialized content knowledge is defined as mathematical knowledge and skill, includes mathematical ideas, mathematical explanations for common rules and procedures. It is unique for teaching. Both parts correspond to Shulman's (1986) dimension about subject matter knowledge (Ball, et al., 2008).

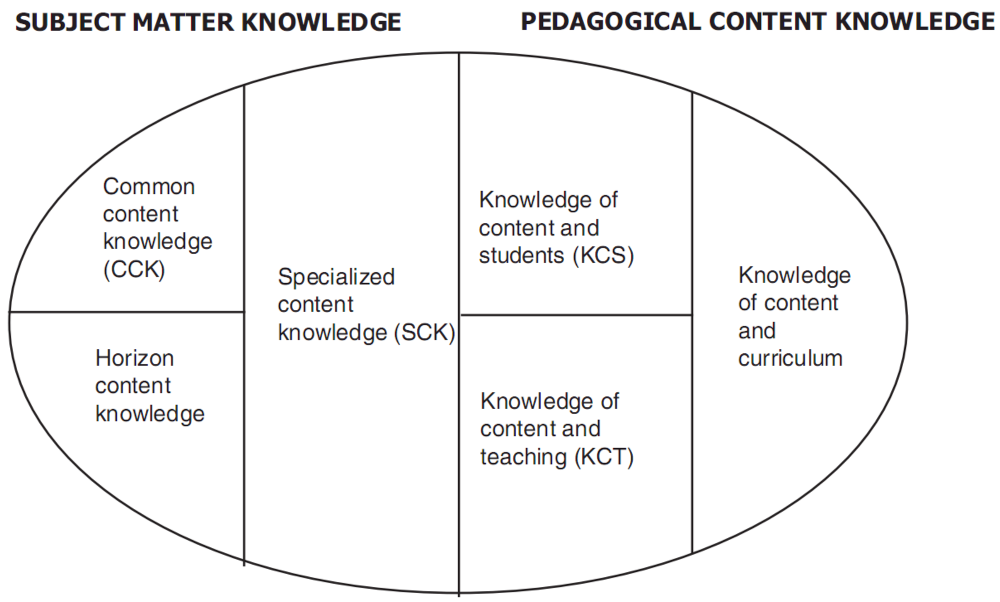

Figure 3 Ball et al.'s Model for mathematics teachers' knowledge, adapted from Ball et al. (2008, p. 403)

In Ball et al.'s (2008) model, pedagogical content knowledge has been divided into three parts: (a) knowledge of content and students, (b) knowledge of content and teaching, and (c) knowledge of curriculum. Knowledge of Content and Students (KCS) part of the model consists of knowledge about students and knowledge about mathematics (Ball, et al., 2008). It has also been defined as "content knowledge intertwined with knowledge of how students think about, know, or learn this particular content" (Hill, et al., 2008, p. 375). The understanding of teachers how students learn specific topics has been emphasized in the Knowledge of Content and Students part. Shulman (1986) also states that the foundation of research on students' thinking and ideas is important for pedagogical knowledge; therefore, KCS corresponds to Shulman's (1986) definition of PCK. Knowledge of Content and Teaching, and Knowledge of Curriculum also are the subset of Shulman's (1986) PCK.

2.1.4 Pierson's Framework of Teacher's TPACK

As stated above, Shulman (1986, 1987), Grossman (1990), and Hill et al. (2008) did not discuss technology and its relationships to pedagogy and content, since the field of education had not encountered the modern computer technologies until 1990s (Mishra & Koehler, 2006). However, the requirement of computer usage in teacher education started in 1990s together with the increasing use of computers as a tool (Wentworth & Earle, 2003). Because of the rising need for technology in education, a number of researchers have proposed to extend the Shulman's idea of PCK by adding the domain of technology. To state differently, Pierson (2001) has worked with technology integration in PCK. She has explained content knowledge, pedagogical knowledge and pedagogical content knowledge in the same way of Shulman's explanation, and added another component, technological knowledge to PCK (see Figure 4). According to Pierson (2001), effective integration of technology in teacher education needs extensive content and pedagogical knowledge. Thus, technological pedagogical content knowledge refers to effective technology integration.

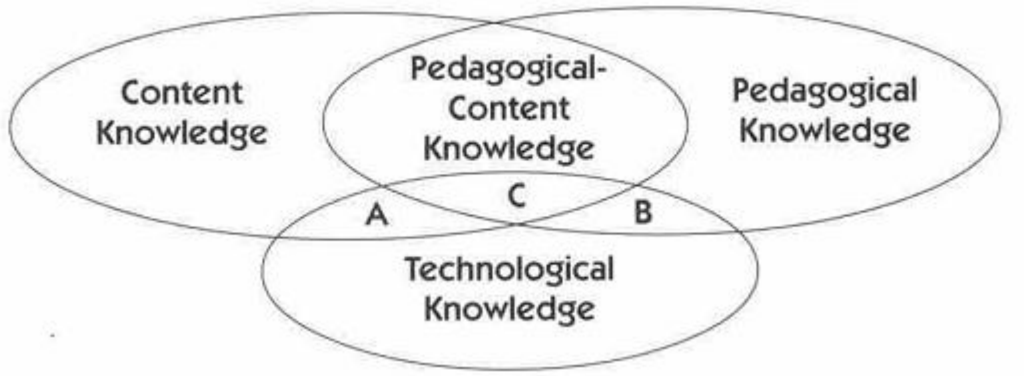

Figure 4 Pierson's Technological Pedagogical Content Knowledge Diagram, adapted from Pierson (2001, p. 427)

Both basic technology competencies of teachers and understanding the characteristics of particular types of technologies that are used in teaching and learning processes constitute the aspect of technological knowledge (Pierson, 2001). Pierson (2001) also notes that the region of A represents knowledge of content-related technology resources, region B represents the methods that have been used to manage and organize learning technology, and region C represents the intersection of three knowledge areas that is technological pedagogical content knowledge.

2.1.5 Koehler and Mishra's Framework

As Pierson (2001), Koehler and Mishra (2005) have used same idea to construct the TPACK. They have combined with technological knowledge, pedagogical knowledge and content knowledge. In other words, Koehler and Mishra (2005) have extended the Shulman's idea of PCK idea by adding the domain of technology. Then, one of the adaptation forms of PCK, which is technological pedagogical content knowledge (TPCK or TPACK), has emerged. The original form of the term is TPCK, but TPCK is later changed to TPACK to make pronunciation easier (Thompson & Mishra, 2008). It composes the interactions among technological knowledge, pedagogical knowledge and content knowledge (Koehler & Mishra, 2005; Koehler & Mishra, 2008; Mishra & Koehler, 2006; Thompson & Mishra, 2007) (see Figure 1). Koehler and Mishra (2005) mainly focus on how teachers can integrate their technology skills rather than what teachers need to know about technology skills. The TPACK framework can show the entire process of technology integration, and identify what is important in the teacher knowledge in terms of using technology for teaching subject matter (Mishra & Koehler, 2006). Many recent TPACK studies have used the current diagrammatic demonstration of TPACK framework developed by Koehler and Mishra (2005) after five years of ongoing research studies. As a result, the TPACK framework has been used in this study. Descriptions of the knowledge domains or components of TPACK have been explained in detail below.

Pedagogical Knowledge

Pedagogical Knowledge (PK) is the knowledge concerning the procedures, processes, practices, strategies, and methods of teaching and learning (Koehler & Mishra, 2005; 2009). Goals and values of education, general classroom management skills, lesson planning, teaching and assessment strategies, and methods are involved in this knowledge (Koehler & Mishra, 2009). Morine-Dershimer and Kent (1999) claimed that pedagogical knowledge can be categorized as ‘general pedagogical knowledge’ and ‘personal pedagogical knowledge’. Classroom communication and discourse, classroom management and organization, and instructional models and strategies affect general pedagogical knowledge; whereas personal beliefs, or perceptions, and practical experience affect personal pedagogical knowledge. Shulman (1987) states that general pedagogical knowledge includes broad principles and strategies of classroom management and organization. Moreover, according to Grossman (1990), general pedagogical knowledge includes general knowledge, beliefs and skills about teaching. Generic theories and methods of instruction, and classroom management are essential parts of general pedagogical knowledge (König, Blömeke, Paine, Schmidt, & Hsieh, 2011).

In the present study, perceptions of preservice mathematics teachers’ knowledge about teaching methods, assessments and selecting materials for teaching have been measured. As an example, item 5, “I can use various teaching approaches in my classroom”, takes part in pedagogical knowledge dimension of this study.

Content Knowledge

"Content Knowledge (CK) is knowledge about the subject matter that is to be learned or taught" (Harris, Mishra, & Koehler, 2009, p. 397). According to Shulman (1986), the content knowledge is located in the mind of teacher, and in the content knowledge, teachers should not only explain the truths of the fields, but they should also explain why the truths are needed and worthy to know. Content knowledge includes knowledge of major facts and concepts in specific field (Grossman, 1990). In the present study, perceptions of preservice mathematics teachers' knowledge on the topic of geometry have been assessed. To exemplify, in content knowledge dimension of this study, item 28, "I can explain geometrical terms in elementary mathematics curriculum", measures participant's perceptions related to their content knowledge.

Technological Knowledge

Defining technological knowledge (TK) is problematic, since it is always in a state of flux (Harris, et al., 2009). However, Koehler and Mishra (2005) state that the technology covers both modern technologies such as computers, the internet and standard technologies such as books and blackboard. The technological knowledge means knowledge about technologies which range from standard technologies such as pencil, paper to more advanced technologies such as Internet, interactive whiteboards (Schmidt, et al., 2009a). Moreover, it includes the skills which require operating particular technologies, knowledge of how to install and remove peripheral devices and software programs (Mishra & Koehler, 2006). Cox (2008) states that TK refers to the ability of using computer technology, manipulating programs and hardware, and producing the desired results.

According to Mishra and Koehler (2006), technology can be changed or may disappear in the years to come. The only thing that matters is to have the ability of learning and adapting new technologies to education, so teachers had better try to improve such skills. In this study, technological knowledge refers to advanced technologies like Internet, computer and their competencies in educational knowledge. The present study aims to assess preservice teachers' perceptions on these technologies. To give an example, item 10, "I know basic computer hardware parts and their functions" measure participant's perceptions related to technological knowledge dimension of this study.

Pedagogical Content Knowledge

In Mishra and Koehler's model, Pedagogical Content Knowledge (PCK) is similar to Shulman's (1986) idea for PCK. The blending of content and pedagogy constitutes PCK. It means that teachers organize particular topics, problems or issues, represent them, adapt different interests and abilities of students, and present for instruction (Shulman, 1987). Niess (2005) and Lowery (2002) define PCK in a similar way as the intersections of knowledge of subject and knowledge of teaching and learning (or pedagogy). PCK is a special form of knowledge, which lumps knowledge of learners, learning, and pedagogy (Ball et. al, 2001). Similarly, Magnusson, Krajcik and Borko (1990) define PCK as

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

According to Ball, Thames, Phelps (2008), PCK includes everything about teachers' knowledge in a particular topic, teachers' actions, reasoning, and beliefs. Besides, it includes essential knowledge of teaching, learning, curriculum, assessment and reporting, pedagogical techniques, and students' prior knowledge (Koehler & Mishra, 2009). Harris et al. (2009) state that PCK also covers alternative teaching strategies in a particular discipline and common content-related misconceptions. In PCK, the knowledge of content-specific activities (or strategies) and the knowledge of representations are combined in order to facilitate student learning (Cox & Graham, 2009).

In this study, preservice mathematics teachers' perceptions related to knowledge of teaching methods, which they will use while teaching the topic of geometry, will be considered in pedagogical content knowledge dimension. In PCK part of the present study, preservice teachers' knowledge on common conceptions and misconceptions about geometry held by the elementary students, their knowledge on the possible sources of these conceptions and misconceptions, their knowledge about the relationship between geometry and other subjects, the strategies that pre-service teachers use to explain the key facts, concepts, principles and proofs on geometry have been investigated. To illustrate, item 32, “I can use various teaching approaches easily when I teach geometry in my classroom”, takes part in pedagogical content knowledge dimension of this study.

Technological Pedagogical Knowledge

Technological Pedagogical Knowledge (TPK) is the knowledge of how teaching and learning can change when specific technologies are used in specific ways. The intersection part of TK and PK constitutes the TPK (Koehler & Mishra, 2009). It is also defined as how to use digital tools for teaching more effectively. McCormick and Thomann (2007) describe TPK as the pedagogy of how to use and apply the technology. In briefly, TPK is defined as teachers’ knowledge about how to use technology in their teaching. It covers having pedagogical knowledge and limiting the technological tools and resources to consider the pedagogical designs and strategies (Harris, et al., 2009). Additionally, Cox (2008) states that understanding technological tools, which are available for teaching, and their weaknesses and strengths are included in TPK.

TPK is particularly important for teachers, since most popular software programs are not designed for educational purposes such as Microsoft Office, blogs or podcasts. Therefore, technological tools should be adapted to education by teachers. Teachers’ TPK can determine the achievement of this adaptation (Koehler & Mishra, 2009). According to Koehler and Mishra (2008), TPK can develop creative flexibility with available tools in order to redesign these programs for specific pedagogical purposes. In line with this, the aim of the present study is to examine preservice mathematics teachers' perceptions on knowledge about identifying and choosing technologies in order to enhance teaching, attractions and drawbacks of those technologies, control the classroom and prepare the technology integrated activities while teaching in the present study. As an example, item 19, "I can choose technologies that enhance the contents of my lessons", measures participant's perceptions related to their technological pedagogical knowledge.

Technological Content Knowledge

Technological Content Knowledge (TCK) is the knowledge that technology and content affect each other (Mishra & Kohler, 2009). TCK is also knowledge of how subject matter is altered by the technology (Koehler & Mishra, 2005). The impact of technology on the practices and knowledge of subject matter can be understood by TCK (Koehler & Mishra, 2008). According to Mishra and Koehler (2006) teachers should know not only the content but also the procedure that content can be changed by the application of technology. Cox (2008) sees TCK from a different standpoint. She extends the Koehler and Mishra's definition. She says that TCK is knowledge of the technologies which can be used in specific subject matter, and how the use of those technologies alters the subject matter for representation or generation a new content. According to Cox (2008), TCK teachers should not only integrate technology in content but also know the rationale for doing so, and they should select or transform of technology in specific content.

In the present research study, perceptions of preservice mathematics teachers' knowledge with technologies in geometry, especially dynamic geometry software's knowledge have been measured. To give an example, item 10, “I know which computer software take part in the area of geometry” measure participant’s perceptions related to technological content knowledge dimension of this study.

Technological Pedagogical Content Knowledge

Technological Pedagogical Content Knowledge (TPACK) refers to the complex interrelationship between technological, pedagogical and content knowledge (Mishra & Kohler, 2006). It is different from these three core knowledge domains in that it is the knowledge about how to use technology in a specific content area by using appropriate pedagogical methods and technologies (Schmidt, et al., 2009a). In other words, in TPACK, teachers know how to use technology for helping students to learn a particular topic (Koehler & Mishra, 2008). Mishra and Koehler (2006) defined TPACK as

> the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help address some of the problems that students face; knowledge of students’ prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones (p. 1029).

Other researchers agree with Mishra and Koehler in terms of the structure of TPACK. Niess (2005) defines TPACK as how particular mathematics concepts can be taught in such a way that technology is used facilitating student comprehension. TPACK refers to integrating the appropriate pedagogy for teaching content and technology, and the appropriate technology for content (McCormick & Thomann, 2007). When teachers are engaged in knowledge of technology, content and pedagogy in their instruction, TPACK occurs (Fath & Genalo, 2008). According to Cox (2008), TPACK is a way of thinking about the dynamic relationships between technology, pedagogy, and specific subject matter in order to help students better understand a particular topic.

For instance, teaching geometry (the content) such as triangle context, trigonometry and the characteristics of shapes can be difficult when using just board and pen, and drawing. However, when a tool (the technology) such as GeoGebra, Geometer's Sketchpad is used for visual representations, or animations and videos (the pedagogy), the particular topic is more easily understood. The knowledge and application of this process refer to TPACK. In this research study, perceptions of preservice mathematics teachers' knowledge about teaching geometry with technology refer to their perceived TPACK knowledge about geometry. To illustrate, item 42, "I can choose technologies that enrich students learning and my teaching in geometry lessons", measures participant's perceptions related to their technological pedagogical content knowledge.

2.2 Research studies on Teachers' TPACK

TPACK is a recent knowledge type of teachers, and when the literature of teachers' TPACK is reviewed, few studies can be seen, which have been conducted related to inservice and preservice teachers. Examples of these TPACK studies have been expressed in below.

2.2.1 Research studies with Inservice Teachers

Koehler and Mishra (2005) have attempted to assess TPACK perceptions of graduate students and instructors. They have examined 13 (9 male and 4 female) graduate students' and four faculty members' (2 male and 2 female) TPACK levels. They designed a course called 'Learning Technology by Design', and they observed the changes between the beginning and end of the semester. The context part of their study consists of online education knowledge. The participants of the study have designed online courses by using different methods. 35 questions have been generated and applied four times throughout the semester. Two questions have been designed in form of short answer, and the rest of them have been designed as 7-point Likert scale from "agree" to "disagree". The results of the study have been analyzed by using t-tests, and they have shown that there is a significant development in the TPACK of participants as well as in their knowledge of technology application. In addition, the results have revealed that the constructs of technology, pedagogy and content affect the TPACK independently (Koehler & Mishra, 2005). Koehler and

Mishra’s (2005) study is important to see the development and process of TPACK framework they have developed (see Figure 2) during this study.

Likewise, Koehler and Mishra (2005), Archambault and Crippen (2009) have studied inservice teachers, who are K-12 online teachers in the United States of America. Mail survey methodology has been used, and 596 teachers have participated in their study. In order to measure online teachers’ knowledge, Archambault and Crippen (2009) have developed a 5-point Likert-type survey instrument, which includes 24 items, based on Koehler and Mishra’s (2005) study. The findings of the study have indicated that the knowledge of online teachers on the domains of PK, CK and PCK are the highest value among TPACK dimensions. When technology dimensions have been considered, knowledge ratings of PK, CK, and PCK domains have reduced (Archambault & Crippen, 2009). Correlations among TPACK domains have revealed that there are small relationships between TK and PK, as well as TK and CK. On the other hand, there is a large correlation between PK and CK (Archambault & Crippen, 2009).

In addition to Archambault and Crippen’s (2009) study, Graham et al. (2009) have developed an instrument about inservice teachers’ TPACK. The aim of Graham et al.’s study is to measure inservice science teachers TPACK. Although Mishra and Koehler’s TPACK framework consists of seven dimensions, Graham et al.’s (2009) instrument just focuses on TK, TCK, TPK and TPACK. The reasons for selecting these dimensions are; TPACK is an extension of PCK, TPK is an extension of PK, and TCK is an extension of CK (Graham, et al., 2009). Their study has been designed as qualitative and quantitative. Graham et al. (2009) notes that firstly, almost 10 days courses have been given to15 inservice teachers. Then, the survey, including 31 items and two open ended questions, has been implemented two times: before courses and after courses. The results of the study indicate that all components have made progress in terms of inservice teachers' confidence levels. TK is the highest values and TCK is the lowest values (Graham, et al., 2009).

It can be concluded from the inservice teachers' TPACK studies that inservice teachers have already known teaching strategies and used them. However, to enhance technology integration in their lessons, the studies indicate that they need supplement courses. Furthermore, based on the literature, the area of teachers' TPACK is brand new. Therefore, it has been not been explored intensively.

2.2.2 Research with Preservice Teachers

When the literature is reviewed, it can be seen that in contrast with the inservice teachers, most of the TPACK studies have been conducted with preservice teachers. For instance, Schmidt et al. (2009a) have measured preservice teachers' TPACK for content areas of mathematics, social studies, science and literacy by using 75-item TPACK survey. The aim of Schmidt et al.'s (2009a) study is to develop and validate an instrument to assess preservice teachers' TPACK. Schmidt et al. (2009a) review the relevant literature and existing survey studies in generating process of their instrument. Besides, their instrument has been prepared as 5-point Likert scale, ranging from "strongly disagree" to "strongly agree". They have also used Koehler and Mishra's (2005) TPACK questionnaire in developing process of their survey. A hundred twenty four students have participated in their study, and the results of their study have shown that factor analysis (between .65 and .92) and reliability analysis (between .80 and .90) were good (Schmidt, et al., 2009a). Some items have been deleted or modified, and the instrument has become a reliable and valid instrument; therefore, it provides adequate information for determining and examining preservice teachers' TPACK (Schmidt, et al., 2009a). The survey of Schmidt et al.'s (2009a) has been used in another study in order to examine the changes in perceived knowledge in TPACK components (Schmidt, et al., 2009b). They state that the participants of the study have been 87 preservice teachers, and pretest-posttest have been conducted in an introductory instructional technology course. Furthermore, a series of paired samples t-tests have been conducted, and changes in all measured variables have been found a statistically significant difference. The results of the Schmidt et al.'s (2009b) study indicate that the change is a higher degree of perceived knowledge at the end of the course. Moreover, the largest differences have been found in TK, TCK, and TPACK dimensions.

Another study conducted with preservice teachers is Niess's (2005) study. She has worked with 22 preservice science and mathematics teachers in science and mathematics content. The development of these teachers' TPCK has been assessed by using qualitative research methodology. Niess (2005) says that all classes of the participants and all assignments have been observed throughout one year and analyzed; firstly, technology courses have been examined, and then microteaching courses and lastly pedagogy courses have been examined. According to Niess (2005), in technology courses part, preservice teachers have learned using various technologies in addition to pedagogical considerations with these technologies and teaching/learning with these technologies. In microteaching courses, preservice teachers have gained teaching experience about four instructional methods; demonstrations, hands on, inductive and deductive modes. In pedagogical courses, preservice teachers have practiced that what they have learned (Niess, 2005). The content knowledge of her study is both scientific and mathematical. Niess (2005) reports that due to the courses, 14 of the 22 students have had a great improvement in their TPACK, and the remaining eight students still need more work to reach high TPACK.

2.2.2.1 Preservice Teachers' TPACK in Turkey

Preservice teachers' TPACK is also a popular topic in Turkey. The ones conducted by Akkaya (2009), Canbolat (2011), Doğan (2012), Şahin (2011), Timur and Taşar (2011), and Uğurlu (2009). To give an example, Akkaya (2009) has studied TPACK in preservice mathematics teachers about derivative concept in terms of 'knowledge of student difficulties'. This study is conducted as a part of a project. Five preservice mathematics teachers have been selected as participants, and within the context of the study, method courses have been examined (Akkaya, 2009). In these courses, Akkaya (2009) explained that preservice mathematics teachers have made a lesson plan, organized a lesson, and implemented their plans with technological tools. The interviews, lesson plans, open-ended questions, problems and the survey about knowledge of derivative concept have been used for data collection for this study (Akkaya, 2009). For assessment, qualitative research methodology has been used, and the results of her study has revealed that there is an improvement in preservice mathematics teachers' TPACK about the content of derivative, especially there is a significant development in CK and PCK dimensions.

In the same project, Uğurlu (2009) has studied measurement and assessment issues in TPCK. 40 preservice mathematics teachers have participated in his study. Both quantitative and qualitative research methodology has been used. He has developed a survey to investigate PCK, and the interviews have been conducted with 10 teachers. According to Uğurlu (2009), the results of the study show that there are positively changes in preservice mathematics teachers' TPACK about measurement and assessment.

Likewise, Akkaya (2009) and Uğurlu (2009), Canbolat (2011) has examined the relationships between preservice mathematics teachers' TPACK and their thinking styles. 288 prospective mathematics teachers have participated in study. Two different instruments, which have been generated by two different researchers, have been used (Canbolat, 2011). Based on results of the study, Canbolat (2011) indicates that judicial, liberal and hierarchic thinking styles are relevant with TPACK components more than other thinking styles.

Similar to the previous studies, Doğan (2012) has studied preservice mathematics teachers in terms of their views about computer use in mathematics education. The data of Doğan’s (2012) study has been collected among 129 fourth grade students of elementary mathematics education during the last semester at the end of the teacher education program. The participants of his study have answered two questions, ‘What do you think about using computers in mathematics education?’ and ‘Can you explain it in the light of your own experiences?’. The reponses of these questions analyzed with qualitatively by using three factors of TPACK; content, technology, and pedagogy (Doğan, 2012). According to results of study, Doğan (2012) says that preservice teachers’ views about computers and their use in mathematics are usually positive. In addition, they have had at least an elementary level of experiences and a reasonable level of confidence about use of computer. However, their ability to use computers for mathematics education is inadequate (Doğan, 2012).

In addition to Akkaya (2009), Uğurlu (2009), Canbolat (2011) and Doğan (2012), some other researchers have studied other preservice teachers and other areas, such as science education, computer education. To exemplify, Timur and Taşar (2011) have investigated the adaptation of science teachers’ self-efficacy instruments about TPCK. They have adapted Graham et al.’s (2009) instrument. They have worked with 393 preservice science teachers, and they have examined the confirmatory factor analysis in order to implement the instrument. Their instrument consists of 31 items and four dimensions: TPACK, TPK, TCK, and TK. The study shows that the results of the factor analysis and reliability analysis are good, and the instrument might be used in Turkey to assess teachers’ self-efficacy about TPACK.

One other preservice teachers' TPACK study has been designed by Şahin (2011). He has worked with preservice teachers at the English Language Teachers Department at the faculty of education. He has developed a 47 item-instrument about TPCK. 348 preservice teachers have participated in validity and reliability process of his study. However, items are more general, since target population of the study is computer education and instructional technology students. Exploratory factor analysis has been conducted, and seven dimensions (CK, PK, TK, PCK, TCK, TPK, and TPCK) have been loaded properly like Schmidt et al.'s (2009) study (Şahin, 2011). Moreover, he has found that there are significant interactions among technology, pedagogy, and content knowledge. The validity and reliability procedures have been applied properly and their results of them are quite high (Şahin, 2011).

2.3 Demographic Differences in TPACK

When the literature of technology is reviewed, there are a few studies related to preservice and inservice teachers' TPACK. However, these studies have investigated the teachers' level of TPACK, or developed and validated TPACK instruments. A few studies have examined the possible differences regarding demographic variables to the TPACK scores (e.g. Canbolat, 2011; Erdoğan & Şahin, 2010; Koh, Chai & Tsai, 2010). These studies state that males are more successful than females about technology, since females have lower experience levels, less positive attitudes, and failure to persist and perform well in educational programs (Sanders, 2006).

Moreover, many female teacher education students are computer-anxious, and they have little computer experience (American Association of University Women Educational Foundation [AAUW], 2000). Dakers, Dow and McNamee (2009) note that females are less interested in technologies when technological knowledge is taught in order to integrate it into teaching and learning process. Thus, there is a difference between male and female participants' degree of interest about technology.

In Erdoğan and Şahin's (2010) study, the relationship between preservice mathematics teachers' TPACK levels and their achievement levels have been examined. A total of 137 preservice mathematics teachers have participated in their study. 42% (n=57) of the participants are males and 58% (n=80) were females. Erdoğan and Şahin (2010) have found that there are the significant differences between male and female students' TPACK dimensions, which are TK, PCK, TCK, TPK and TPCK, in favor of males. The effects of departmental affiliation on TPACK have also been examined in their study, and a significant difference between primary and secondary mathematics teacher candidates' TPACK domains in favor of primary one is found (Erdoğan & Şahin, 2010).

In addition to Erdoğan and Şahin (2010), Koh, Chai and Tsai (2010) have examined Singapore preservice teachers' TPACK by using 29 items of Schmidt et al.'s (2009) survey. A total of 1185 preservice teachers have participated in the study. 68.3 % (n=809) of the participants are females and 31.7% (n=376) are males. The differences of gender, age and teaching level on TPACK have been examined.

The results show that male preservice teachers' TPACK are generally higher than females. Moreover, male preservice teachers have had a more positive attitude, higher confidence and competency perceptions in terms of computer use. However, the age and teaching level do not differ among preservice teachers' TPACK as strong as gender (Koh, Chai, & Tsai, 2010).

Canbolat (2011) has also found a significant difference in favor of male preservice teachers in her study. She has investigated the relationship between preservice mathematics teachers' TPACK and their thinking styles. She has examined the influences of gender, class level, and computer possession on TPACK. A total of 288 preservice mathematics teachers have participated in the study. 71 % (n=204) of the participants are males and 29 % (n=84) are females. In addition, 143 participants are fourth grade students and 198 participants are equipped with their own computer. The results of the study indicate that male preservice mathematics teachers have had higher TK, TCK, TPK and TPCK levels (Canbolat, 2011). The fourth grade students have had higher PK, CK, TPK and TPCK levels. Moreover, preservice mathematics teachers, which have their own computer, had higher TK, TPK, TCK, and TPCK levels (Canbolat, 2011).

The object of interest in this study is whether these differences are distinct in terms of teacher's knowledge or not. Based on the literature, demographic variables present valuable information about differences of teachers' TPACK. Therefore, one of the aims of this study has been to examine the differences regarding demographic variables on perceptions of preservice mathematics teachers on their TPACK scores on geometry.

2.4 Summary of the Literature Review

Teachers' knowledge is important issue to build up and enhance students' learning, since teaching mathematics is a complex structure, therefore well-prepared teachers are needed (NCTM, 2000). The review of the literature part has begun with the introduction of teacher knowledge frameworks. To illustrate Ball (1990a; 1990b; 2000), Borko, et. al (1992), Grossman (1990), Hill, et al. (2008), Shulman (1986, 1987), and Tamir (1988). When the literature is reviewed, after 1986, exploration of teachers' knowledge increased rapidly, focusing on the framework suggested by Shulman (1986). According to these studies, teachers' knowledge depends on their subject matter knowledge or content knowledge, pedagogical knowledge and pedagogical content knowledge.

Although Shulman's (1986) PCK model is comprehensible, it is not adequate after the field of education encountered the modern computer technologies (Mishra & Koehler, 2006). Together with the growth in the use of computers as a tool in education, the requirement of technology knowledge in teacher education has increased. Thus, a number of researchers (Guerrero, 2010; Mishra & Koehler, 2006; Pierson, 2001 Schmidt, et al., 2009a) have proposed to extend the Shulman's idea of PCK by adding the technology domain. After this integration, Shulman's (1986) PCK model has been adapted to Mishra and Koehler's (2006) TPACK framework.

Teachers' TPACK depends on seven knowledge domains: TK, CK, PK, PCK, TCK, TPK, and TPACK. Effective teaching with technology also depends highly on these knowledge domains (Harris, Mishra, & Koehler, 2009).

Literature review has revealed that many researchers have examined pre-service and in-service teachers' TPACK on different context (Akkaya, 2009; Archambault & Crippen, 2009; Canbolat, 2011; Graham et al., 2009; Koh, Chai, & Tsai, 2010; Koehler & Mishra, 2005; Niess, 2005; Şahin, 2011; Schmidt, et al., 2009b; Timur & Taşar, 2011; Uğurlu, 2009), and their results have emphasized that the increase in preservice and inservice teachers' technological pedagogical content knowledge depend on their courses. Moreover, demographic variables have affected the teachers' TPACK scores.

However, as states in the significant of the study and literature parts of the present study, there are few studies focusing on preservice teachers' TPACK, especially in geometry context. Besides, there is a need to develop an instrument and to conduct more studies in terms of mathematics teachers' TPACK. Therefore, the aims of this research study have been to investigate perceptions of preservice mathematics teachers on their TPACK regarding geometry and the possible differences regarding demographic variables preservice mathematics teachers' TPACK.

CHAPTER III

METHOD

This chapter gives detail information about research design and procedures of the current research study. This methodology part of the study consists of seven subtopics namely; research design, participants and sampling procedure, instrumentation and development process, data collection procedures, data analysis procedures, internal and external validity threats, and lastly assumptions and limitations of the study.

3.1 The Research Design of the Study

In this study, it has been intended to investigate perceptions of preservice mathematics teachers' technological pedagogical content knowledge regarding geometry. Moreover, it has been examined the relationships between TPACK components and possible demographic differences concerning preservice mathematics teachers' perceptions of TPACK. In accordance with this purpose, the characteristics of preservice mathematics teachers' perceptions regarding TPACK have been described by implementing a questionnaire to the sample. Thus, in this research study, survey research methodology has been used.

According to Fraenkel and Wallen (2006), survey research is used to determine the specific characteristics of a group. Moreover, gathering information via survey implementation from a sample at a certain time point is the feature of a cross-sectional survey research (Fraenkel & Wallen, 2006), therefore it can be stated that in this study, a cross-sectional survey research is used.

The other aim of this study is to detect possible gender and year of enrollment differences and relationships among components of TPACK framework. Fraenkel and Wallen (2006) state that the possibility of relationships between two or more variables is investigated in correlational studies. Therefore, in this study, correlational research methodology has been used. On the other hand, the design of the study can be a causal-comparative research due to the fact that the variables of gender and year of enrollment are categorical. Causal-comparative research methodology is used in order to compare two or more groups of subjects, and it involves at least one categorical variable such as gender, year of enrollment (Fraenkel & Wallen, 2006). Considering the purposes together with the research design definitions, it can be stated that the present study includes harmony of survey, correlational and causal-comparative research methodology.

3.2 Participants and Sampling Procedure

Target population of the present study is prospective mathematics teachers who are enrolled in elementary mathematics education departments of Education Faculties of all public universities located in Central Anatolia. There are 18 public universities in Central Anatolia, and 9 of them have elementary mathematics education program. Two universities of them have been used in pilot study of instrument. Two hundred seventy nine prospective mathematics teachers have participated in the pilot study. The data of main study have been gathered from other seven universities. The accessible population of the study consists of Turkish prospective elementary mathematics teachers who are studying in these seven universities. In order to determine the sample, courses, which are taken from elementary mathematics students, is considered. The junior (3rd grade) and senior (4th grade) elementary mathematics students, who are enrolled in nine universities, has been selected to the sample, since third and fourth grade students have already taken courses related to technology and pedagogy. To exemplify, the lessons of computer assisted mathematics instruction and method courses are offered in fifth or sixth semester of elementary mathematics education undergraduate program. Furthermore, courses of school experience are taken in seventh and eighth semester. According to Fraenkel and Wallen (2006), choosing a certain group of people who are available for study is a convenience sampling. Therefore, convenience sampling method is used in this study. The sample of the study consists of about 780 juniors and seniors in the undergraduate program of elementary mathematics education in the academic year of 2011-2012. Demographic characteristics of the participants in main study related to gender, year of enrollment, teaching experience, technology use and courses are provided in Table 1.

According to Table 1, most of the participants are female (69,3 %). About 61% of the participants are junior, and 67,7 % of the participants have had teaching experience such as giving private lesson during their undergraduate education. When the participants have been asked how frequent they plan to use technology in geometry teaching, most of them (53,1 %, n=412) state that they will usually use technology in their geometry teaching. Moreover, four of them will never plan to use technology and 52 of them will always plan to use technology in geometry teaching.

Table 1

Demographic Characteristics of the Sample

	n	**Percent**
Gender		
Male	239	30,7
Female	540	69,3
Year of Enrollment		
Junior	475	60,9
Senior	305	39,1
Teaching Experience		
Yes	523	67,7
No	249	32,3
Planned technology use frequency		
Never	4	0,5
Sometimes	33	4,3
Frequently	275	35,4
Usually	412	53,1
Always	52	6,7
Courses		
Methods of Teaching Mathematics I	753	96,5
Methods of Teaching Mathematics II	707	90,6
School Experience I	313	40,1
School Experience II	301	38,6

The last demographic information about the participants is related to the courses, which they took in their universities. Most of them take "Methods of Teaching Mathematics I" (96,5 %) and "Methods of Teaching Mathematics II" (90,6 %) courses. Almost 40 % of preservice elementary mathematics teachers have taken courses of school experience.

3.3 Instrument of the Study

Perceived TPACK regarding Geometry questionnaire (see Appendix B) has been developed to determine preservice teachers' TPACK levels on geometry. The literature of technological pedagogical content knowledge has been reviewed by using ERIC, EBCOhost, and ULAKBIM as databases. The research studies that obtained from these databases have been explored carefully, and it appears that researchers have barely studied TPACK on specific subject. Therefore, in the preparation process of this study, two comprehensive TPACK studies, which belong to Schmidt et al. (2009) and Şahin (2011), are selected in order to guide and adapt the new TPACK instrument regarding geometry.

The reason for selecting Schmidt et al.'s (2009) study is that Schmidt et al. (2009) generate TPACK instrument based on the Mishra and Koehler's (2005) TPACK framework which is the comprehensive structure in order to determine preservice teachers' TPACK. Moreover, Schmidt et al.'s (2009) instrument is used in most of the TPACK studies in the literature due to the high statistical results. The reason for selecting Şahin (2011) study is that his instrument has been implemented in Turkey, so factor of cultural differences is eliminated, and also the statistical results of his instrument are practicable. Besides, necessary qualifications of being teachers, which are produced Ministry of National Education, are used in the developing process of perceived TPACK on geometry instrument.

To consider these two instruments and teacher qualifications, 54 items have been written to assess preservice mathematics teachers' perceptions of TPACK regarding geometry. Four items (item 1, 2, 3, 4) of technological knowledge, six items (item 8, 9, 10, 12, 13, 14) of pedagogical knowledge, two items (item 24, 28) of content knowledge, three items (item 31, 36, 37) of pedagogical content knowledge, three items (item 16, 19, 22) of technological pedagogical knowledge, one item (item 40) of technological content knowledge, and four items (item 44, 45, 46, 47) of technological pedagogical content knowledge have been adapted from Schmidt et al.'s (2009) and Şahin's (2011) instrument. The rest of 31 items have been written based on the literature.

These items have been evaluated by two experts, from mathematics education and educational measurement departments, and based on their evaluations some items are revised. Moreover, these items consist of seven components, which are perceptions of preservice mathematics teachers on their technological knowledge, content knowledge, pedagogical knowledge, pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge. Distribution of the items is given in the Table 2.

Table 2

Distribution of the First Version of Technological Pedagogical Content Knowledge Regarding Geometry Instrument

Components	Number of items	Item numbers
Technological Knowledge (TK)	7	Item 1 to 7
Content Knowledge (CK)	8	Item 24 to 30
Pedagogical Knowledge (PK)	8	Item 8 to 15
Pedagogical Content Knowledge (PCK)	8	Item 31 to 39
Technological Content Knowledge (TCK)	6	Item 40 to 43, 51, 52
Technological Pedagogical Knowledge (TPK)	8	Item 16 to 23
Technological Pedagogical Content Knowledge (TPACK)	9	Item 44 to 50, 53, 54

Likert scales are used in this survey because they are very flexible, easy to assess and constructed more easily (Hopkins, 1998). According to Krosnick and Fabrigar's (1997) study shows that the appropriate length of a rating scale is 5 to 7 points, since in these points, scales seem to be more reliable and valid. Therefore, the answers of the participants have been collected by using the 6-point Likert scale format ranging from strongly disagree to strongly agree. Demographic information including gender, class, lessons and teaching experience have also been requested. Pilot study of the instrument is explained detailed in the next section and sample items from the scale are demonstrated in Table 3.

Table 3

Sample Items from the Perceived TPACK regarding Geometry Instrument

Item Number	Dimension	Sample Item
2	PK	I can adapt my teaching based on what students understand or do not understand a topic.
11	TK	I can use basic computer software (e.g. Windows, Microsoft Office).
16	TPK	I can choose technologies to enhance the teaching approaches I use in my classroom.
23	CK	I have sufficient knowledge about geometry, which is located in mathematics curriculum.
30	PCK	I can select effective teaching approaches to guide students' thinking and learning process in geometry.
39	TCK	I know about computer software (e.g. Geometer's Sketchpad, GeoGebra) which is related to geometry topics.
41	TPACK	I can combine technology and teaching approaches effectively when I teach geometry.

3.3.1 Developmental Process of the Instrument

Pilot study and main study have been used in development process of the instrument in this study. In order to develop valid and reliable instrument PASW Statistics 18 software program and LISREL 8.8 have been used. Pilot study has been used for exploratory factor analysis and reliability analysis. Additionally, main study has been used for confirmatory factor analysis.

The pilot study of the first version of perceived TPACK about geometry instrument (see Appendix A) including 54 items has been piloted with 279 (225 female and 54 male) prospective mathematics teachers who are enrolled in two state universities in Ankara. There are 159 junior students (57%) and 120 senior students (43%) in pilot study. Validity and reliability analysis are explained below.

3.3.1.1 Validity Analysis of the Perceived TPACK regarding Geometry Instrument

For validity analysis of the instrument, cognitive interview with preservice mathematics teachers and exploratory factor analysis are conducted, and expert opinions are taken. Cognitive interviewing is conducted with two preservice mathematics teachers for face validity. Based on the interview, some spelling mistakes are fixed, and slender appearance changes are applied.

For the purpose of content validation, the instrument is sent to 3 experts to be evaluated. Two of the experts are from the department of mathematics education who have so many research studies about technology, prospective teacher education and technology education in mathematics. The other expert is from science education department who has many research studies on prospective teachers’ technological pedagogical content knowledge. These experts are asked to assess the quality of each item, verify matching of items to the corresponding components, and provide further suggestions. Some items have been revised to make them clearer based on experts’ opinion. For instance, Item 34, “I can give misconception example about geometry which is located in elementary mathematics curriculum”, is changed as “I can determine students’ misconceptions about geometry topics” because it is suggested that the last one is more clear and appropriate for the misconception content. Item 40, "I know which technologies are used in geometry lesson", which belongs to TCK, is also changed. The word, "lesson", is ejected, because of evoking pedagogy. Moreover, explanatory notes are added between parentheses in item 6, item 43, item 48, and item 49, and some spelling mistakes are fixed in order to make more clear and understandable.

Exploratory Factor Analysis

Exploratory factor analysis is conducted for construct validity. Before conducting factor analysis, sample size, the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) value, Bartlett's test of sphericity value, and correlation matrix are examined in order to ensure feasibility of factor analysis. Bartlett's test of sphericity is significant (BTS value=10357.86, $p<.001$), which means that the correlation matrix is significantly different from an identity matrix. KMO value is about 0.94, which is higher than 0.60. According to Tabachnick and Fidell's (2007) study, both results are appropriate to perform factor analysis. Gorsuch (1983) suggests that sample size should be at least 100, and *N:p* ratio should be minimum 5. According to Cattell (1978), this ratio should be in the range of 3 to 6. In this study, there are 54 items and 279 participants. Thus, the sample size assumption is assured. After checking the assumptions, exploratory factor analysis with maximum likelihood estimation has been conducted. For the extraction technique, common factor analysis is preferred to principal components analysis (PCA), since PCA is used only for data reduction. Moreover, discrimination between shared and unique variance cannot be explained by PCA (Costello & Osborne, 2005). Fabrigar, Wegener, MacCallum, and Strahan (1999) state that maximum likelihood is the best choice, when data are normally distributed. Therefore, maximum likelihood has been used for a factor extraction method. According to Costello and Osborne's (2005) study, oblique rotation method is used in social sciences because it gives more accurate and more reproducible solution. Thus, in this study, oblique rotation (direct oblimin) has been used for the rotation method. For missing data, the pairwise case has been used in analysis in order not to lose all of them.

Based on the criteria of Kaiser (1960), eigenvalues should be 1 or more to consist of factors. The 54 items have been factor analyzed, and nine factors have emerged with eigenvalues greater than 1. Table 4 shows these eigenvalues. However, Pallant (2007) states that if too many components are extracted based on the Kaiser criterion, it should be better to look also the scree plot. A change (or elbow) should be looked at in the shape of the plot. Scree plot has seen in Figure 5.

Table 4

Initial Eigenvalues of the Factors

Number of the Factor	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	18,983	35,153	35,153
2	5,417	10,032	45,186
3	2,707	5,013	50,198
4	2,024	3,748	53,946
5	1,833	3,394	57,341
6	1,401	2,594	59,935
7	1,296	2,400	62,335
8	1,139	2,109	64,443
9	1,002	1,855	66,298
10	,967	1,791	68,090
11	,881	1,632	69,722

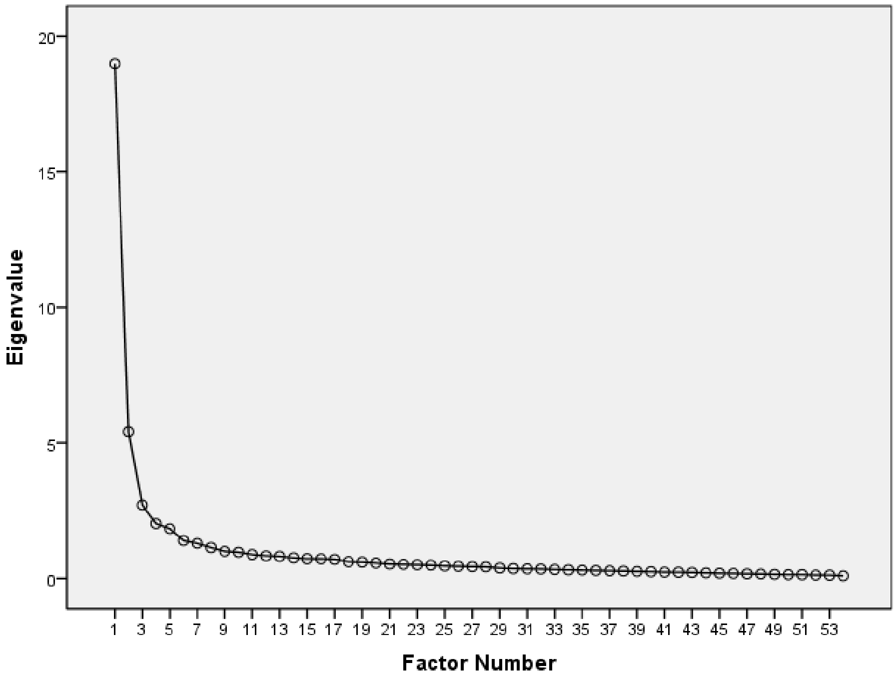

Figure 5 Scree Plot

In factor analysis, there are nine factors that have eigenvalue higher than 1 and these explains about 66.3% of the variance. However, it is seen more proper to extract seven factors by looking at the scree plot. The first seven factors explain about 62.3% of the variance. Thus, based on the criteria of Kaiser (1960), and scree plot, there are seven factors (TK, CK, PK, TPK, TCK, PCK, and TPCK) in the perceived TPACK about geometry instrument. In order to interpret seven factors, pattern matrix table (see Appendix C), which shows the factor loadings of each of variables, has been used. The order of factors and number of loading items are determined based on the pattern matrix table. The loaded factors names are that first factor is Technological Pedagogical Content Knowledge, second factor is Technological Content Knowledge, third factor is Technological Pedagogical Knowledge, fourth factor is Technological Knowledge, fifth factor is Pedagogical Knowledge, sixth factor is Content Knowledge, and the last factor is Pedagogical Content Knowledge.

Stevens (2009) suggests that all items' pattern coefficients should be higher than 0.30 for loading the factors. Therefore, based on Steven's criteria, seven items have loaded on more than one factor, and two items have not loaded anywhere. After investigate the content of all items, three items have been deleted and seven items have been revised. Before deleting any items, expert opinion has been obtained in order not to break the content of instrument. The deleted items are shown in Table 5.

Table 5

The Removed Items from Percieved TPACK regarding Geometry Instrument

Item Number	Removed Item
21	I can evaluate students' learning levels effectively when I use technology.
39	I can use different measurement and assessment tools about geometry.
42	I can find animations and simulations related to geometry easily.

The reason for deleting item 21 is that the item, which is related to TPK, has loaded in both PK and PCK dimension, and students may not understand this item. Item 39 took part in PCK dimension. However, it has loaded in totally different dimensions; TPACK, TK, and CK. Thus, it should be required wiping. Item 42, which takes part in TCK dimension, has loaded in TPACK and TK. Students can be understood selection in this item, moreover; item 48 is similar to this item, and it measures the idea of selection. Therefore, item 42 can be deleted. On the other hand, item 3, item 20, item 27, item 28, item 31, item 37, and item 49 have been revised, since they have loaded more than one factor. Item 3 took part in TK dimension. The word, "effectively", has been removed from item 3, since it has been considered to evoke pedagogy. In item 20 and item 37, the word, "in my lessons", has been changed because students can understand the word as their lessons in university. Item 27, which exists in CK, has loaded both CK and TPACK. The reason for this can be the word, "Science and Technology", so it is deleted. The final version of Perceived TPACK regarding Geometry Instrument is given in Appendix B.

Confirmatory Factor Analysis

For the construct validity, following the exploratory factor analysis, confirmatory factor analysis is conducted by using LISREL 8.8. Bangert (2006) states that confirmatory factor analysis is "conducted to test the stability and replicability of the latent model produced by the exploratory factor analysis" (p. 236). In this study, seven factor TPACK structure is estimated in exploratory factor analysis. Therefore, confirmatory factor analysis is conducted based on these seven factors by using the data of main study.

Multiple goodness-of-fit tests are used to evaluate the fit between the hypothesized TPACK measurement model and the data from main study. These are the Root Mean Square Error Approximation (RMSEA; Steiger and Lind 1980), the Normed Fit Index (NFI; Bentler and Bonett 1980), the Comparative Fit Index (CFI; Bentler, 1990), and the Root Mean Square Residuals (RMR; Byrne, 1998). According to Bangert (2006), the value of RMSEA describes the discrepancy or error between the hypothesized model and an estimated population model. Browne and Cudeck (1993) report that the RMSEA value about .05 indicates a close fit of the model, and the value ranging from .05 to .08 represents a reasonable fit. Furthermore, they suggest not using a model with a RMSEA greater than .10. The value of NFI and CFI greater than .90 indicates a good fit to the data (Kline, 1998). RMR values less than .05 are indicative of a close fit, and values ranging from .05 to .08 are indicative of a reasonable fit (Brown, 2006; Byrne, 1998). Although chi-square statistics has been used commonly in the literature, it has been criticized for being highly sensitive to sample size (Bentler, 1990; Tabachnick & Fidell, 2007). In large samples, chi-square can detect trivial differences between observed and model-implied covariance matrices (Bollen 1989; Hoyle 1995; Kline 1998). However, according to Kelloway (1998), the ratio of between chi-square and degrees of freedom can be used instead of the value of chi-square. The value of chi-square / degrees of freedom ratios less than 5 indicates a good fit to the data (Kelloway, 1998).

Results from the LISREL output indicate that the seven-factor structure on TPACK model fit well to the data with all fit indices (χ^2/df = 3.90; NFI=0.97; CFI=0.98) indicating a good fit except for RMSEA (=0.061) and RMR (=0.058), which indicates a reasonable fit. However, the value of RMSEA and RMR are too closed on the value of good fit model. In addition, all parameters are found to be significant (see Appendix E). It means that each item has a significant contribution to the corresponding dimension. In brief, the results of the confirmatory factor analysis indicate that seven factor model of TPACK is a good fit.

3.3.1.2 Reliability Analysis of the Perceived TPACK regarding Geometry Instrument

In the pilot study, the reliability of each dimensions of TPACK framework and the reliability of the entire scale have been examined. Cronbach's coefficient alpha is calculated by using PASW 18. Cronbach alpha coefficient of the whole scale is 0.96. Cronbach alpha coefficient of each dimension ranges from 0.83 to 0.92. The alpha value of 0.6-0.7 indicates acceptable reliability, and 0.8 or higher indicates good reliability (Cronbach, 1951). Therefore, it could be deduced that the instrument of this study has a good reliability.

In conclusion, the evidence collected during this study provides that the Perceived TPACK regarding Geometry Instrument is valid and reliable.

3.4 Data Collection Procedure

The data collection starts after the necessary permissions are taken firstly from the Research Center for Applied Ethics ethical committee at Middle East Technical University and then from other universities. After the all necessary permissions have been taken, pilot study of the instrument has been conducted. According to the results of the pilot study data collection process for the main study has been completed. The data collection period started at December, 2011 and lasted until June, 2012.

The instrument has been implemented in the classroom settings to the participants in both the pilot and the actual study. All students are filled in the questionnaire at the beginning of their courses. The approximate time of filling the scale is 10 - 15 minutes. All data have been collected by researcher. Before implementing the survey, all students have been informed about the purpose of the study and the content of the survey. The researcher has also stayed in the class to answer the further questions about survey. Volunteer students participate in this study. Moreover, in order to make them feel comfortable and give honest responds, no question is asked that identify the identity of participants.

3.5 Data Analysis Procedure

Data which is gathered from the prospective mathematics teachers who are enrolled in elementary mathematics education program of the selected universities are imported to the PASW18, and are analyzed with descriptive and inferential statistics. In the survey the statement of “Strongly Disagree” is valued with 1 whereas the statement of “Strongly Agree” is valued with 6. Demographics parts of the instrument are coded as the value of 1 and 2, and the frequency question part is coded the value from 1 to 5 corresponding to never to always, respectively. The means of each of the component of TPACK is calculated. Moreover, the pairwise case is used for missing data in order not to lose all of them.

In order to answer the first research question descriptive information about the components of TPACK are calculated. To answer the second research question, pearson product moment correlation analysis is used. The relationships among the components of the TPACK framework have been identified based on the result of the analysis. In third research question, whether there are a possible relationship between demographic information of prospective elementary mathematics teachers and their perceptions of TPACK is investigated. Thus, two-way MANOVA is conducted to answer the third research question.

3.6 Internal and External Validity

The threats to the internal and external validity and precautions taken to overcome these threats are discussed in this section.

3.6.1 Internal Validity

Fraenkel and Wallen (2006) state that the internal validity is "…observed differences on the dependent variable are directly related to the independent variable and not due to some other unintended variable" (p.169). In this study, there are some threats to debar from internal validity; subject characteristics, mortality (loss of subjects), location, and instrumentation.

Subject characteristics threat refers to influence of some certain characteristics of the participants on any variable which is aimed to be measured in the study (Fraenkel & Wallen, 2006). Subject characteristic threat can be occurred, as the participants' extraordinary interest in the technology and the usage of it in the teaching. This threat has been accepted as a limitation, and the results of the present study have been discussed considering this limitation.

Mortality threat refers to loss of the participants who could not complete the questionnaire as the study progresses (Fraenkel & Wallen, 2006). In this study, mortality threat can be occur as some participants could give up answering the scales which could be considered as a threat to the internal validity. However, it can be eliminated to choose all junior and senior students who enrolled in elementary mathematics teacher education department from all state universities of Central

Anatolia in Turkey. Moreover, before implementing the scale the purpose of the study is explained, and just voluntary students participate into the study. Incomplete scales have also been removed from the data of this research study.

Location threat is that the particular locations, in which data are collected, can affect the responses of participants undesirably (Fraenkel & Wallen, 2006). Although, it is not possible to keep location constant for all participants, all of administrations of the instrument are also conducted in regular classroom environments of the teacher education programs. Thus, location threat can be minimized.

Instrumentation threat refers to changes in the instrument during the data collection process, effects of characteristics of the data collectors on participants, and bias on the part of the data collectors (Fraenkel & Wallen, 2006). In order to eliminate instrumentation threat, researcher has explained clearly the aims of study to all participants. Moreover, the questionnaire of the study is designed to use Likert type scale in order not to exhaust the participants. Therefore, possible instrumentation decay threat can be minimized or eliminated.

3.6.2 External Validity

According to Frankel and Wallen (2006), external validity defines as "the extent to which the results of a study can be generalized determines the external validity of the study" (p. 104). In the current study, the sample consists of all junior and senior Turkish students, those who enrolled in elementary mathematics education departments of the state universities in Central Anatolia. Thus, convenience sampling method is used. This situation can be a threat for generalizability.

Frankel and Wallen (2006) describe the ecological generalizability as "…the degree to which the results of a study can be extended to other settings and conditions" (p. 106). Moreover, Frankel and Wallen (2006) claim that when convenience sampling method is used, ecological generalizability is made more reasonable instead of population generalizability. Characteristics of the sample, which are given in detail, affect the generalizability. Therefore, it can be claimed that the results of this study is desirable for the ecological generalizability since participants of the study have similar conditions and experiences with the population.

3.7 Assumptions and Limitations of the Study

Prospective mathematics teachers' perception of TPACK regarding geometry has been measured by using the instrument which is based on self-assessment survey instrument. Therefore, there is a risk, as some respondents can overestimate or underestimate their ability. Participants may be prone to give answers biasedly. However, it is assumed that participants gave answers honestly.

Frankel and Wallen (2006) state that using nonrandom sampling method limits the generalizability of research. The participants of this study are selected from third and fourth year levels of the elementary mathematics education program in specific regions of Turkey, so convenience sampling methodology, which is one of the nonrandom sampling methods, is used. This can be a limitation for generalizability.

Preservice mathematics teachers' judgments regarding their capability of technological pedagogical content knowledge in their instructional practices have been measured by self-assessment items in this study. Therefore, some items in the instrument of present study are parallel to self-efficacy items. However, the term, perceived technological pedagogical content knowledge", has been used for the instrument of this research study based on the literature and some research studies such as Koh, Chai, and Tsai (2010), Lee and Tsai (2010), Schmidt, et al. (2009a) because all items of the instrument cannot measure preservice mathematics teachers' self-efficacy related to TPACK. Thus, it can be a limitation of this study.

CHAPTER IV

RESULTS

This study intends to explore on perceptions of Turkish prospective elementary mathematics teachers' TPACK regarding geometry and the relationships between TPACK components. Furthermore, a possible relationship between demographic information of prospective elementary mathematics teachers and their perceptions of TPACK is investigated.

In this chapter of the study consists the results of the research questions. These questions and their results have been explained respectively.

4.1 Preservice Mathematics Teachers' Perceptions of TPACK regarding Geometry

The aim of the first research question is to explore the levels of preservice mathematics teachers' perceptions on their technological pedagogical content knowledge regarding geometry. In order to answer this question, descriptive analysis has been conducted. Table 6 indicates mean values and standard deviations related to perceptions of participants' TPACK concerning geometry for each component. Table 7 and Table 8 show mean values and standard deviations regarding perceptions of participants' TPACK components in terms of gender and year of enrollment.

Table 6

Descriptive Analysis for Perceived TPACK regarding Geometry Instrument

	Mean	SD	Skewness	Kurtosis
Pedagogical Knowledge	4.5982	.59982	-.847	2.757
Technological Knowledge	4.1872	.96073	-.379	-.134
Content Knowledge	4.8214	.68532	-.745	1.642
Pedagogical Content Knowledge	4.7480	.63877	-.908	2.701
Technological Pedagogical Knowledge	4.4274	.76119	-.730	.844
Technological Content Knowledge	3.7202	1.07963	-.263	-.601
Technological Pedagogical Content Knowledge	4.2698	.86471	-.653	.394

Higher mean scores refer higher perceptions on knowledge for prospective mathematics teachers. According to Table 6, the highest mean value of preservice mathematics teachers' perceptions on knowledge belongs to content knowledge (CK). Furthermore, the participants feel less competent in technological content knowledge (TCK) than the other components of the TPACK. Most of mean values about perceptions of prospective mathematics teachers on knowledge domains ranges from four to five out of six. Considering these values, it may be inferred that preservice mathematics teachers' perceptions on their TPACK related to geometry is higher than moderate.

Table 7

Descriptive Statistics in terms of Gender

	Gender					
	Male			Female		
	N	Mean	SD	N	Mean	SD
PK	239	4.5689	.61909	540	4.6093	.59015
TK	239	4.5873	.86730	540	4.0139	.94501
CK	239	4.8792	.68512	540	4.7981	.68308
PCK	239	4.7442	.68651	540	4.7487	.61736
TPK	239	4.5989	.70629	540	4.3543	.77082
TCK	239	3.9035	1.10753	540	3.6431	1.05498
TPACK	239	4.4780	.80110	540	4.1812	.87380

Table 7 indicates that mean scores of TPACK components in terms of gender. Both male and females participants, the highest mean values belong to content knowledge. On the other hand, the lowest mean values of them are technological content knowledge. Although the number of males is smaller than females, males mean scores in knowledge domains related to technology and content knowledge are higher than females. Furthermore, both male and female participants' perception related to pedagogical content knowledge almost same. Only in pedagogy knowledge, females feel more competent than males.

Table 8

Descriptive Statistics in terms of Year of Enrollment

	Year of Enrollment					
	Junior			Senior		
	N	Mean	SD	N	Mean	SD
PK	475	4.5728	.02787	305	4.6378	.03359
TK	475	4.1611	.04363	305	4.2279	.05590
CK	475	4.7832	.03167	305	4.8810	.03861
PCK	475	4.7221	.03015	305	4.7882	.03481
TPK	475	4.4217	.03521	305	4.4362	.04310
TCK	475	3.6484	.04963	305	3.8319	.06119
TPACK	475	4.2186	.04157	305	4.3495	.04530

Likewise Table 6 and Table 7, Table 8 indicate that the highest mean values of preservice mathematics teachers' perceptions on knowledge in terms of year of enrollment belong to content knowledge (CK). On the other hand, the lowest mean values of preservice mathematics teachers' perceptions on knowledge in terms of year of enrollment belong to technological content knowledge (TCK). Although the number of 3rd grade students is more than 4th grade students, all the mean scores of 4th grade students in TPACK components are higher than the mean scores of 3rd grade students. It means that senior participants feel more competent than junior participants. Moreover, mean scores regarding knowledge domains of technology are the lowest scores among TPACK components for 3rd grade and 4th grade students.

4.2 The Relationships among the Components of TPACK

In second research question, the relationships among the components of TPACK have been investigated. In order to answer it, Pearson product moment correlation analysis is conducted. Before starting the analysis, assumptions have been checked in preliminary analyses.

Assumptions of Pearson Product-Moment Correlation Analyses

According to Pallant (2007) there were five assumptions for correlational analysis, namely measurement, related pairs, independence of observations, normality, linearity, and homoscedasticity. Results and related graphs of preliminary analyses are presented in Appendix D.

This study has seven dependent variables as the components of perceived TPACK. All of them are continuous at interval level. Thus, the level of measurement assumption is ensured. According to Pallant (2007), all scores of the variables for each participant are necessary. There is no missing data in the study, therefore the assumption of related pairs is provided. As mentioned before, it is assumed that the participants have not influenced each other during the implementation process.

To ensure normality, descriptive statistics, histograms and normality plots are controlled. Scores and tables on each variable indicate that knowledge domains are normally distributed. Moreover, skewness and kurtosis value indicate an acceptable range from -2 to +2 except for kurtosis values of PK and PCK (see Table 6). In order to overcome kurtosis values of PK and PCK, descriptives, histograms and Q-Q plot have been examined. These inspections indicate that mean values and 5% trimmed mean values of participants are close, and histograms and Q-Q plots look like normally distributed. Therefore, the normality assumption has been supported (Pallant, 2007).

Linearity and homoscedasticity are checked via the scatterplot (Pallant, 2007). Visual examination of the scatterplot reveals that most of distributions are linear shape not in curve shape (see Appendix D). Thus they indicate that there is no violation in linearity assumption. In addition, scatterplot indicates the strength of the relationship among variables (Pallant, 2007). If the relationship is weak, the shape of scatterplot resembles a blob-type arrangement. However, in strong relationship, the shape of scatterplot resembles a vague cigar shape (Pallant, 2007). In order to check the assumption of homoscedasticity, scatterplots, histograms and normality plots have been examined. Visual examinations show that most of scatterplots look like cigar shape. Based on the examinations, it can be stated that there is no violation in homoscedasticity assumption.

Pearson Product-Moment Correlation Analyses

After conducting the preliminary analysis for checking the assumptions, pearson product moment correlations are calculated. Alpha level is determined at .05 significance level of analysis, and listwise deletion is performed with 780 subjects. The results of the correlational analysis are presented in Table 9.

The examination of Pearson Correlation values indicates that there is statistically significant positive correlation among all of the components of perceived TPACK about geometry.

Table 9

Pearson Product-Moment Correlations among the Components of Perceived TPACK regarding Geometry

	PK	TK	TPK	CK	PCK	TCK	TPACK
PK	1,000	---					
TK	,327**	1,000	---				
TPK	,527**	,740**	1,000	---			
CK	,517**	,330**	,451**	1,000	---		
PCK	,606**	,312**	,494**	,759**	1,000	---	
TCK	,300**	,528**	,545**	,333**	,370**	1,000	---
TPACK	,454**	,685**	,776**	,476**	,537**	,739**	1,000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

To determine the strength of the relationship, Cohen (1988) suggests a guideline: if the values of the correlation coefficient range from .10 to .29, there is a small relationship between variables. If the values of the correlation coefficient range from .30 to .49, there is a medium relationship between variables. If the values of the correlation coefficient above from .50, there is a large or strong relationship between variables (Cohen, 1988). Therefore, Table 9 indicates that there is no small relationship; all relationships among TPACK components are medium or large.

The highest correlation is between technological pedagogical content knowledge and technological pedagogical knowledge at $\alpha = .01$ with $r = .776$, p=.000. The second highest correlation is between pedagogical content knowledge and content knowledge at $r = .759$, $p = .000$. On the other hand, the smallest correlation is between technological content knowledge and pedagogical knowledge at $r = .30$, $p = .000$. The r values corresponding to the remaining correlations range from .312 to .740.

4.3 Demographic Diversities of Preservice Mathematics Teachers' TPACK

The aim of third research question is to explore possible demographic differences between perceptions of preservice mathematics teachers' technological pedagogical content knowledge regarding geometry. This study consists of one dependent variable TPACK framework and two independent variables (gender, year of enrollment). Each of two independent variables has two levels; female, male, and junior, senior. Besides, one dependent variable consists of seven dimensions (TK, CK, PK, PCK, TPK, TCK, and TPACK). Therefore, according to Pallant (2007) two-way multivariate analysis of variance (MANOVA) has been conducted to investigate mean differences among gender and class factors. Before MANOVA, the preliminary analysis has been conducted to ensure assumptions.

Assumptions of MANOVA

Pallant (2007) state that MANOVA has six assumptions: sample size, normality, outliers, linearity, multicollinearity and singularity, and homogeneity of variance-covariance matrices. The minimum required number of participants for each cell is three (Pallant, 2007). Four levels of two independent variables (male, female, junior and senior) and seven dependent variables consist of 28 cells; therefore, minimum required participants are 84. The sample of this study is 780. Thus, sample size assumption is not violated.

According to Pallant (2007), in order to ensure normality assumption, both univariate normality and multivariate normality have been checked. Univariate normality has been checked in research question two by examining skewness, kurtosis values and by visual examination of histograms. In order to check multivariate normality, Mahalanobis distances should be calculated. Then the value of distance should be compared with a chi-square table (Pallant, 2007). In this table, for 7 variables, critical value is indicated as 24.32. The maximum Mahalanobis distance for gender is 65.305 and for class is 65.099, which are larger than critical value. This means that there is ‘multivariate outliers’ in the data. Mahalanobis distances indicate that the first 16 cases are higher than the critical value; however, the Cook’s distances of these cases are lower than 1. In addition, Pallant (2007) states that if there is a reasonable size data file, the outliers can be involved in analysis. Hence, these are remained in the analysis.

Linearity assumption has been ensured in assumption parts of second research question by examining scatterplots. The assumption of multicollinearity and singularity are checked by calculating the correlation coefficients between dependent variables (see Table 9). Highly correlated dependent variables refer to as multicollinearity. Furthermore, correlations up around .8 or .9 are the reason for removing strongly correlated pairs of dependent variables (Pallant, 2007). The correlation coefficients between the dependent variables range from .300 to .776, which are smaller than .8. Therefore, there is no violation of this assumption.

The last assumption, homogeneity of variance-covariance matrices, has been checked by using Box's M Test of Equality of Covariance Matrices. Moreover, Levene's Test of Equality of Error Variances has been used to check this assumption (Pallant, 2007). In Box's M Test of Equality of Covariance Matrices, if the Sig. value is larger than .001, the assumption is not violated. Furthermore, the Sig. value of Levene's Test of Equality of Error Variances should be larger than alpha level (.01) in order not to violate the assumption (Tabachnick & Fidell, 2007). However, ın this study, Sig. value of Box's M Test of Equality of Covariance Matrices is .00, which is less than .001. The reason for this can be large sample size because Tabachnick and Fidell (2007) state that Box's M can be too strict in large sample size. Then, in order to check this assumption Levene's Test has been examined. The results of Levene's Test indicate that this assumption has been assured at $\alpha = .01$ for TK ($p = .047$), TPK ($p = .087$), PCK ($p = .095$), PK ($p = .099$), CK ($p = .483$), and TCK ($p = .829$), and whereas it has not been assured for, TPACK ($p = .003$). It means that the population variances are not equal in TPACK variable. The violation of this assumption causes the robustness of the F statistics. However, in order to ensure the robustness of the F statistic, Tabachnic and Fidell (2007) suggest a calculating an F_{max} value, which is "the ratio of the largest cell variance to the smallest. If sample sizes are relatively equal (within a ratio of 4 to 1 or less for largest to smallest cell size), an F_{max} value as much as 10 is acceptable." (p. 86). The largest cell size is 338, and the smallest one

103. Besides, F_{max} value for homogeneity of variances tests with TPACK is 4.75, which is smaller than 10. Therefore, the F value is robust.

Two-way MANOVA

After conducting the preliminary analysis for checking the assumptions, two-way MANOVA has been conducted. The results indicate that the interaction effect between class and gender is not statistically significant, F (7, 769) =.94, p = .48. In addition, there is no significant mean difference between junior and senior participants in terms of overall dependent variables F (7, 769) = 1.73, p = .10. However, there is a statistically significant mean difference for male and female participants in terms of overall dependent variables, F (7, 769) = 12.35, p = .000; Wilks' Lambda = .90 with medium effect size (partial eta squared = .101).

In order to investigate whether male and female participants are different in all dependent variables or not, Tests of Between-Subjects Effects have been examined (Pallant, 2007). A Bonferonni adjustment has been used to examine statistical significance. In this adjustment, original alpha level of .01 is divided the number of dependent variables. Thus, the new alpha level is .001. Then, the results for the dependent variables are considered separately, and the differences occur in TPK, F (1, 775) = 17.84, p = .000, partial eta squared = .022; TPCK, F (1, 775) = 20.03, p = .000, partial eta squared = .025; and TK, F (1, 777) = 66.14, p = .000, partial eta squared = .079. Table 10 indicates the results of the follow-up analysis.

Table 10

Follow-up Analysis

Source	Dependent Variable	df	F	Sig. (p)	Partial Eta Squared
Gender	PK	1	,726	,395	,001
	TK	1	66,138	,000*	,079
	CK	1	1,916	,167	,002
	PCK	1	,002	,961	,000
	TPK	1	17,837	,000*	,022
	TCK	1	8,680	,003	,011
	TPCK	1	20,034	,000*	,025

* Significant at Bonferonni adjusted alpha level of .001

Although follow-up analysis demonstrates that males and females are different in terms of TK, TPK, TPCK, which one had higher scores is not known. To find this out, mean scores of males and females have been examined (see Table 7).

According to the statistics obtained from the follow-up analysis and descriptive table, there are statistically significant mean differences between males and females in technological pedagogical knowledge scores, F (1, 775) = 17.84, p = .000, partial eta squared = .022; technological pedagogical content knowledge scores, F (1, 775) = 20.03, p = .000, partial eta squared = .025; and technological knowledge scores, F (1, 775) = 66.14, p = .000, partial eta squared = .079. Male participants have higher perceptions than females in these three dimensions. However, the magnitudes of the all differences between males and females are small.

4.4 Summary

In this research study, perceptions of preservice mathematics teachers' technological pedagogical content knowledge regarding geometry have been investigated. Furthermore, the relationships between TPACK components and possible demographic differences concerning preservice mathematics teachers' perceptions of TPACK have been examined. In accordance with this purpose, some statistical analyses have conducted.

The results indicate that Turkish preservice elementary mathematics teachers' perceptions of TPACK related to geometry is higher than moderate. Preservice mathematics teachers feel more competent in content knowledge (CK). However, they feel less competent in technological content knowledge (TCK) than the other components of the TPACK.

The correlation analysis clarify that the preservice mathematics teachers' perceptions regarding TPACK components are positively correlated. All relationships among TPACK components are medium or large. The highest correlation is between technological pedagogical content knowledge and technological pedagogical knowledge. On the other hand, the correlation between technological content knowledge and pedagogical knowledge is the smallest one.

Related to the roles of year of enrollment and gender on perceptions of preservice mathematics teachers' TPACK regarding geometry, no interaction effect between the independent variables exist. The results show that there is no significant difference between third and fourth grade students' perceptions of TPACK components.

However, statistically significant differences between males and females preservice mathematics teachers’ perceptions of TPACK components have been found in favor of males. Male participants have higher perceptions related to technological knowledge, technological pedagogical knowledge and technological pedagogical content knowledge. The effect sizes for these differences indicate that the results have small practical significance.

CHAPTER V

DISCUSSION

In the present study, it has been aimed to examine perception levels of preservice mathematics teachers' technological pedagogical content knowledge regarding geometry and its dimensions, and to investigate some possible diversities caused by their demographic profiles. This chapter starts to discuss the findings based on the research questions. Then, it continues implications for educational practices, and concludes with prospects for future research studies.

5.1 The Perceptions of Preservice Mathematics Teachers' TPACK

The first research question of the present study is related to the exploration of preservice mathematics teachers' perception levels in technological pedagogical content knowledge regarding geometry. In order to answer this question, descriptive information has been used. The results indicate that perceptions of preservice mathematics teachers' TPACK regarding geometry is not so low or so high, it is moderate. Furthermore, preservice mathematics teachers have positive perceptions about TPACK, since the mean value of TPACK dimension has ranked as the positive values. The highest mean value of preservice mathematics teachers' perceptions is content knowledge. This means that preservice mathematics teachers feel more competent and sophisticated related to geometry knowledge among TPACK components. On the other hand, the least mean values of preservice mathematics teachers' perceptions correspond to technological knowledge and technological content knowledge. This shows that participants do not feel themselves competent and sophisticated in knowledge and applications of computer and dynamic geometry software. These findings supported the results of other studies. To give an example, Doğan (2012) state that although preservice mathematics teachers are familiar with using computer, their competencies of using computers in mathematics education are inadequate. Moreover, Erdoğan and Şahin (2010) have found that mathematics teacher candidates have low technological content knowledge. The reason for lower mean scores in technological content knowledge can be inadequate courses. To state differently, technological courses, which are offered in the curriculum of elementary mathematics teacher education programs are not comprehensive enough to enhance preservice mathematics teachers' technological content knowledge. In addition, most of preservice elementary mathematics teachers' may not take any courses related to using technology in geometry teaching and learning. Besides, preservice mathematics teachers who have only taken technology-oriented courses may not get any information regarding how to use technology in geometry teaching and learning. Therefore, this situation can be a reason for the lowest technological content knowledge. On the other hand, the reason for high content knowledge can be the backgrounds of participants. Preservice mathematics teachers have coped with geometry since their elementary education. Therefore, they may feel themselves more competent in the area of geometry.

According to the results, preservice mathematics teachers' perceptions related to pedagogical knowledge, content knowledge and pedagogical content knowledge are higher than other dimensions which are connected with technology. It means that participants feel themselves less competent and sophisticated in technological knowledge, technological pedagogical knowledge, technological content knowledge, and technological pedagogical content knowledge. The reason for this situation can be integration problem. Preservice mathematics teachers may still think pedagogical knowledge, content knowledge and technological knowledge separately and, they cannot integrate these three knowledge domains. Furthermore, although they can feel themselves knowledgeable regarding technology components, they may not set these components in their courses. In other words, participants may gain their technology experience out of their undergraduate education, and they cannot use their technology experience for educational purposes. Therefore, it is clearly seen that undergraduate education of participants has had little influence on their construction of computer knowledge for educational purposes.

However, the demographic characteristics of the participants of this study indicate that 53.1 percent of preservice teachers usually want to use technology in their future classrooms, and 6.7 percent of them always want to use technology in their future classrooms. On the other hand, four of preservice mathematics teachers (0.5 percent) never want to use technology in their future classrooms. Therefore, it can be said that preservice mathematics teachers are open-minded, and they have positive feelings toward teaching mathematics with computers. Their informal experiences concerning technology can be a reason for this result.

5.2 The Relationships among the Components of TPACK

The second research question of the present study is related to the investigation of the relationships among perceptions of preservice mathematics teachers' technological pedagogical content knowledge and its components. The results indicate that there are positive relationships among the components of the TPACK, and all of the relationships are statistically significant. Results of other TPACK studies support the findings of the present study. As an example, in Şahin's (2011) study, he has found statistically significant correlations among the all dimensions of TPACK. Furthermore, Timur and Taşar (2011) have found high relationship between the TPACK, TPK, TCK, and TK components. Considering the findings from the present study and literature suggest that technological knowledge, pedagogical knowledge, and content knowledge should be treated in together, not separately (Koehler & Mishra, 2009; Niess, 2005; Şahin, 2011). Besides, Mishra and Koehler (2006) state that "quality teaching requires developing a nuanced understanding of the complex relationships among technology, content, and pedagogy, and using this understanding to develop appropriate, context-specific strategies and representation (p.1029)". Therefore, it can be claimed that the present study supports the intertwined relationship among technological knowledge, content knowledge and pedagogy knowledge as stated in the literature.

According to the results of the pearson product moment correlation analysis, the highest relationships exist between the domains which are related to technology. Moreover, the relationships among pedagogical knowledge, content knowledge and pedagogical content knowledge are high. However, the lowest relationships exist between knowledge domains regarding technology and knowledge domains of pedagogy, content and pedagogical content. As stated above, integration problem can be a reason for this results. It means that preservice mathematics teachers have not integrated technology into pedagogical knowledge, content knowledge adequately yet. Preservice mathematics teachers may still think separately regarding knowledge domains of technology and knowledge domains of pedagogy, content and pedagogical content.

5.3 Demographic Diversities of Preservice Mathematics Teachers' TPACK

The third research question of the present study is to examine the possible demographic differences regarding perceptions of preservice mathematics teachers' technological pedagogical content knowledge. Possible differences in terms of gender and year of enrollment have been investigated by two-way MANOVA. The results indicate that there is no interaction between gender and year of enrollment. Although there is no difference among TPACK components in terms of year of enrollment, statistically significant differences among TPACK components in terms of gender are found.

Male and female preservice mathematics teachers' perceptions are different in three components of TPACK, namely technological knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge in favor of male participants. On the other hand there are not statistically significant differences in the mean scores of the male and female preservice mathematics teachers' perceptions in terms of pedagogical knowledge, content knowledge, pedagogical content knowledge, and technological content knowledge. This finding is consistent with the other studies findings, such as Canbolat (2011), Erdoğan and Şahin (2010), and Koh, Chai and Tsai (2010). Erdoğan and Şahin (2010), and Canbolat (2011) state that male preservice mathematics teachers have had higher TK, TCK, TPK and TPCK levels compare to females. Besides, Koh, Chai and Tsai (2010) find that male preservice teachers have higher technological knowledge than females. The reason for these diversities in favor of males may be the conception of technology as masculine in nature. Dakers et al. (2009) and Sanders (2006) assert that females are less interested in technologies than males when technological knowledge integrated into teaching and learning. Therefore, interesting level may cause this difference. Males can be more interested in technology and technological devices compare to females, and males may use more complex technology than females. Moreover, males may have more positive attitudes toward technology than females. Because of that, males can have higher mean scores in terms of technological knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge.

The analysis for exploring the roles of year of enrollment on perceptions of preservice mathematics teachers' technological pedagogical content knowledge show that there is no difference between perceptions of junior and senior elementary mathematics students' TPACK. This may be due to the fact that junior and senior students have taken some courses regarding technology and pedagogy. In Turkey, the courses related to educational technology start in second year of teacher education programs, and the courses related to pedagogy start in first year. Therefore, junior and senior students have already taken the same courses in their undergraduate education. This could be the reason for non-significant difference between juniors and seniors.

5.4 Implications and Recommendations

In this section, some implications and recommendations for educational policy makers, instructors, teacher education programs, and teachers of mathematics have been mentioned in accordance with the discussion of the results.

One of the aims of present study is to gather descriptive information about perceptions of preservice mathematics teachers' TPACK related to geometry. As mentioned earlier, TPACK has been studied in the last few decades. Therefore, the findings of the study can be used as foreknowledge in further research studies. The present study shows that perceptions of preservice teachers related to technology components of TPACK framework are the lowest knowledge domains especially technological content knowledge in the field of geometry. This meant that preservice teachers' knowledge of technology is inadequate, especially technology in geometry. Moreover, the results show that preservice mathematics teachers have an integration problem concerning three knowledge bases. According to Suharwoto and Lee (2005), the role of the courses in the knowledge of technology is very high and the courses in teacher preparation program should be designed very carefully. Therefore, in order to enhance their technological content knowledge, the courses of technology in geometry, which are offered in undergraduate education, should be increased or reformed. More elective courses related to using technology in mathematics education could be added in the elementary mathematics teachers' education curriculum. In addition, contents of the existing courses could be changed in order to enhance preservice mathematics teachers' perceptions of TPACK. More subjects related to technology and geometry could be added into the existing courses.

Regarding the relationships among preservice elementary mathematics teachers' perceptions of TPACK components, the findings refer that there are strong relationships between TPACK, TPK, TCK, and TK. Based on the literature, in TPACK, there are also the complex interrelationship among content, pedagogy and technology, and their intersections. However, results of the present study indicate that the relationships between knowledge domains regarding technology and knowledge domains of pedagogy, content and pedagogical content are not as high as the relationships between each other. Therefore, in order to increase the relationships between knowledge domains related to technology and other knowledge domains, teacher education programs should modify to develop preservice teachers' TPACK in an integrated manner. Instead of giving technology course, content course and pedagogy course separately, all these three courses could be merged in a given course.

Today's preservice mathematics constitutes the future mathematics teachers. Hence, if preservice mathematics teachers have more knowledge about technology and its applications in education, in future, they can integrate technology into their potential classrooms easily. As mentioned earlier, in Turkey, MoNE carry out many projects such as FATİH, e-okul in order to improve using technology in schools. Because of the fact that preservice mathematics teachers can need high level knowledge related to TPACK. In accordance with this approach, the results of this study can be helpful in making reforms in teacher education programs to raise mathematics teachers with enough TPACK and effective technology integration skills.

This study just aimed to serve as a descriptive research on perceptions of preservice mathematics teachers' TPACK related to geometry in Central Anatolia region in Turkey. The development of their perceptions on TPACK has not examined as a part of this study. With the light of the information that the present study has yielded, further research studies could be performed to analyze the pathways of preservice mathematics teachers' TPACK development. This study just gives an overview about the relationships between and among the components of preservice mathematics teachers' TPACK.

Moreover, this research study has been limited to perceptions of preservice mathematics teachers' TPACK in the field of geometry. More studies could be conducted about other areas in mathematics. Findings of this study indicate that although there are diversity between male and female perceptions regarding TPACK and its components, there is not difference between junior and senior students of elementary mathematics education. However, only preservice elementary mathematics teachers have been used as sample in the present study. Therefore, the results may be different in secondary level since secondary mathematics teachers specialize in a particular subject area whereas elementary mathematics teachers tend to be generalist.

Technological pedagogical content knowledge has been studied in last few decades. As this research study, there are some other studies which aim to validate the TPACK framework, but it is still a controversial issue. Although, all TPACK components exist in this study, in the literature, some of the components of the TPACK have been disappeared in some studies. Therefore, more research studies are needed to validate the TPACK framework and to understand its structure.

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APPENDICES

APPENDIX A

First Version of Perceived TPACK regarding Geometry Instrument

Geometri Konusunda Teknolojik Pedagojik Alan Bilgisi (TPAB) Anketi

Sayın öğretmen adayı,

Teknolojik Pedagojik Alan Bilgisi (TPAB) öğretmenlerin teknoloji bilgilerini ve öğretmenlik bilgilerini belli disiplinleri öğretirken nasıl kullandığıyla ilgili düşünme biçimidir. Bu çalışma sizlerin ilköğretim matematik öğretim programında bahsedilen geometri konularındaki (geometrik cisimler, şekiller, çokgenler, çember, doğrular ve açılar, örüntü ve süslemeler vs.) Teknolojik Pedagojik Alan Bilgilerinizi ölçmek amacıyla hazırlanmıştır.

Lütfen aşağıda ifade edilen her maddeyi okuyup, sizin düşüncenizi en iyi yansıtan *sadece bir* seçeneği işaretleyiniz. Kişisel bilgileriniz ve cevaplarınız gizli tutulacaktır. Anketi doldurmanız yaklaşık 15 dakikanızı alacaktır. Anketi doldurmaya zaman ayırdığınız için teşekkür ederim.

Arş.Gör. Aykut BULUT
ODTÜ – İlköğretim Fen ve Matematik Eğitimi

	Kesinlikle katılmıyorum	**Katılmıyorum**	**Biraz katılmıyorum**	**Biraz katılıyorum**	**Katılıyorum**	**Kesinlikle katılıyorum**
1. Bilgisayarda çalışırken karşılaştığım teknik bir sorunu nasıl giderebileceğimi biliyorum.	1	2	3	4	5	6
2. Temel bilgisayar donanım parçalarını (Ekran Kartı, Anakart, Ana Bellek, RAM vb.) ve işlevlerini biliyorum.	1	2	3	4	5	6
3. Temel bilgisayar yazılımlarını (Windows, Office, Powerpoint, Media Player vb.) etkin bir şekilde kullanabilirim.	1	2	3	4	5	6
4. Sunum araçlarını (projeksiyon cihazı, akıllı tahta, tepegöz vb.) etkin bir şekilde kullanabilirim.	1	2	3	4	5	6
5. Yeni karşılaştığım teknolojileri (donanım veya yazılım)	1	2	3	4	5	6

kullanmayı kolaylıkla öğrenebilirim.						
6. Aradığım görsel ve işitsel teknolojileri (animasyon, simülasyon vb.) kolaylıkla bulabilirim (internet yoluya, satın alarak vb.).	1	2	3	4	5	6
7. Bilgisayarda ortaya çıkan yazılımsal bir sorunu kolaylıkla çözebilirim.	1	2	3	4	5	6
8. Öğrencilerin sınıf içi performanslarını nasıl değerlendireceğimi biliyorum.	1	2	3	4	5	6
9. Ders anlatımımı öğrencilerin anladıkları veya anlamadıkları konulara göre uyarlayabilirim.	1	2	3	4	5	6
10. Öğretim yöntemimi farklı öğrenme seviyelerindeki öğrencilere göre düzenleyebilirim.	1	2	3	4	5	6
11. Öğrenmeyi zenginleştirmek için etkili materyal, kaynak ve etkinlik seçebilirim.	1	2	3	4	5	6
12. Derslerimde çeşitli öğretim yöntemlerini kullanabilirim.	1	2	3	4	5	6
13. Ders anlatırken sınıfıma etkili bir şekilde hakim olabilirim.	1	2	3	4	5	6
14. Farklı ölçme yöntem ve tekniklerini etkili bir şekilde kullanabilirim.	1	2	3	4	5	6
15. Bireysel farklılıkları göz önüne alarak bir dersi planlayabilirim.	1	2	3	4	5	6
16. Öğretim yönteminin etkili olmasını sağlayacak teknolojiler seçebilirim.	1	2	3	4	5	6
17. Derslerimde kullanacağım öğretim yöntemime uygun teknolojileri (donanım veya yazılım) belirleyebilirim.	1	2	3	4	5	6
18. Derslerimde teknolojinin kullanıldığı etkinlikler oluşturabilirim.	1	2	3	4	5	6
19. Dersin içeriğini zenginleştirecek teknolojiler seçebilirim.	1	2	3	4	5	6
20. Derslerimde teknolojiyi kullanırken sınıfı rahatlıkla kontrol edebilirim.	1	2	3	4	5	6
21. Teknolojiyi kullanırken öğrencilerin öğrenme düzeylerini etkili bir biçimde değerlendirebilirim.	1	2	3	4	5	6
22. Yeni bir teknolojinin eğitim-öğretimde kullanılabilirliğini değerlendirebilirim.	1	2	3	4	5	6
23. Teknolojiden etkili bir şekilde yararlanmamı sağlayacak şekilde dersimi planlayabilirim.	1	2	3	4	5	6
24. İlköğretim matematik öğretim programındaki geometri konularıyla ilgili (geometrik cisimler, çokgenler, çember, örüntü ve süslemeler vb.) yeterli bilgiye sahibim.	1	2	3	4	5	6
25. İlköğretim matematik öğretim programındaki geometri konularıyla ilgili soruları kolaylıkla cevaplayabilirim.	1	2	3	4	5	6

26. İlköğretim matematik öğretim programındaki geometri konularını günlük yaşamla ilişkilendirebilirim.	1	2	3	4	5	6
27. Geometri konularını matematiğin diğer öğrenme alanlarıyla ve farklı disiplinlerle (Türkçe, Sosyal Bilgiler, Fen ve Teknoloji vb.) ilişkilendirebilirim.	1	2	3	4	5	6
28. Geometriyle ilgili araştırmalar yaparak alanıma katkı sağlayabilirim.	1	2	3	4	5	6
29. İlköğretim programında yer alan geometri konularındaki matematiksel kavramları (doğru, nokta, açı kavramı vb.) açıklayabilirim.	1	2	3	4	5	6
30. İlköğretim programında yer alan geometri konularındaki ispatları yapabilirim.	1	2	3	4	5	6
31. Öğrencilerin geometri konularındaki düşünme ve öğrenme süreçlerine yardımcı olacak etkili öğretim yöntemlerini seçebilirim.	1	2	3	4	5	6
32. Öğrencilerin geometri konularındaki kavram yanılgılarını belirleyebilirim.	1	2	3	4	5	6
33. Geometriyi öğretirken çeşitli öğretim yöntemlerini kolaylıkla kullanabilirim.	1	2	3	4	5	6
34. Öğrencilerin geometri konularıyla ilgili kavram yanılgılarının nedenlerini belirleyebilirim.	1	2	3	4	5	6
35. Öğrencilerin geometri konularındaki öğrenme düzeylerini belirleyebilirim.	1	2	3	4	5	6
36. Geometriyle ilgili öğrencileri öğrenmeye güdüleyebilecek bir ders planlayabilirim.	1	2	3	4	5	6
37. Derslerimde geometriyi diğer matematik konularıyla ilişkilendirebilirim.	1	2	3	4	5	6
38. Öğrencilerin ihtiyaçlarını göz önüne alarak geometriyle ilgili etkinlikler hazırlayabilirim.	1	2	3	4	5	6
39. Geometriyle ilgili çeşitli ölçme ve değerlendirme araçlarını (yazılı yoklama, çoktan seçmeli test, portfolyo, kavram haritası vb.) kullanabilirim.	1	2	3	4	5	6
40. Geometride hangi tür teknolojilerin (bilgisayar, yazılım, materyal vb.) kullanıldığını biliyorum.	1	2	3	4	5	6
41. Geometri konularında hangi bilgisayar yazılımlarının (Geometer's Sketchpad, Logo, Geogebra, C.A.R. vb) olduğunu biliyorum.	1	2	3	4	5	6
42. Geometri ile ilgili animasyonları ve simülasyonları kolaylıkla bulabilirim.	1	2	3	4	5	6
43. Hangi donanımsal teknolojilerin (projeksiyon cihazı, hesap makinesi, akıllı tahta vb.) geometri konularında kullanılabileceğini biliyorum.	1	2	3	4	5	6
44. Geometriyi öğretirken teknolojiyi ve öğretim yöntemimi etkili bir şekilde bir araya getirebilirim.	1	2	3	4	5	6

45. Geometri dersinde öğrencilerin öğrenimini ve öğretimimi zenginleştirecek teknolojiler seçebilirim.	1	2	3	4	5	6
46. Diğer öğretmenlerin geometri öğretiminde, teknolojiyi ve öğretim yöntemlerini bir araya getirmelerine yardımcı olabilirim.	1	2	3	4	5	6
47. Teknolojiyi ve farklı öğretim yöntemlerini kullanarak geometri konularını etkili bir şekilde anlatabilirim.	1	2	3	4	5	6
48. Görsel ve işitsel teknolojileri (animasyon, simülasyon vb.) geometri öğretirken kolaylıkla kullanabilirim.	1	2	3	4	5	6
49. Geometri öğretiminde teknoloji kullanırken öğrencilerin karşılaştığı bir sorunu (donanımsal veya yazılımsal) rahatlıkla çözebilirim.	1	2	3	4	5	6
50. Teknolojiyi ve öğretim yöntemimi etkili bir biçimde bir araya getirerek geometri dersimi planlayabilirim.	1	2	3	4	5	6
51. Dinamik geometri ve matematik yazılımlarını (Geometer's Sketchpad, Geogebra, Cabri, vb.) nasıl etkili kullanabileceğimi biliyorum.	1	2	3	4	5	6
52. Dinamik geometri ve matematik yazılımlarını kullanırken bir sorunla karşılaştığımda nasıl çözeceğimi biliyorum.	1	2	3	4	5	6
53. Geometri konularını öğretmek için dinamik geometri ve matematik yazılımlarını kullanabilirim.	1	2	3	4	5	6
54. Geometriyi dinamik geometri ve matematik yazılımları ile öğretirken öğrencilerin öğrenme düzeylerini etkili bir şekilde değerlendirebilirim.	1	2	3	4	5	6

Kişisel Bilgiler

1. Cinsiyetiniz : ☐ Bay ☐ Bayan

2. Sınıfınız : ☐ 3. Sınıf ☐ 4. Sınıf

3. Lütfen aldığınız dersleri işaretleyiniz *(Birden fazla seçenek işaretleyebilirsiniz. Halen almakta olduğunuz dersleri de dikkate alınız.)* :

☐ Özel Öğretim Yöntemleri I ☐ Okul Deneyimi

☐ Özel Öğretim Yöntemleri II ☐ Öğretmenlik Uygulaması

4. Matematik eğitiminde teknoloji kullanımıyla ilgili hangi ders(leri) aldınız?

____

5. Öğretmenlik deneyiminiz var mı? (Okullar, Dersaneler, Özel ders vb. ☐Evet ☐Hayır

6. İleride teknolojiyi derslerinizde ne kadar sıklıkla kullanmayı planlıyorsunuz?

☐ Hiçbir zaman ☐ Nadiren ☐ Bazen ☐ Sıklıkla ☐ Her zaman

7. Eğer ileride sınıflarınızda istediğiniz teknolojilere ulaşma imkânınız olursa, geometriyi öğretirken hangi teknolojileri kullanmayı planladığınızı kısaca nedenleriyle birlikte açıklayınız.

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APPENDIX B

Final Version of Perceived TPACK regarding Geometry Instrument

Geometri Konusunda Teknolojik Pedagojik Alan Bilgisi (TPAB) Anketi

Sayın öğretmen adayı,

Teknolojik Pedagojik Alan Bilgisi (TPAB) öğretmenlerin teknoloji bilgilerini ve öğretmenlik bilgilerini belli disiplinleri öğretirken nasıl kullandığıyla ilgili düşünme biçimidir. Bu çalışma sizlerin ilköğretim matematik öğretim programında bahsedilen geometri konularındaki (geometrik cisimler, şekiller, çokgenler, çember, doğrular ve açılar, örüntü ve süslemeler vs.) Teknolojik Pedagojik Alan Bilgilerinizi ölçmek amacıyla hazırlanmıştır.

Lütfen aşağıda ifade edilen her maddeyi okuyup, sizin düşüncenizi en iyi yansıtan *sadece bir* seçeneği işaretleyiniz. Kişisel bilgileriniz ve cevaplarınız gizli tutulacaktır. Anketi doldurmanız yaklaşık 15 dakikanızı alacaktır. Anketi doldurmaya zaman ayırdığınız için teşekkür ederim.

Arş.Gör. Aykut BULUT
ODTÜ – İlköğretim Fen ve Matematik Eğitimi

	Kesinlikle katılmıyorum	**Katılmıyorum**	**Biraz katılmıyorum**	**Biraz katılıyorum**	**Katılıyorum**	**Kesinlikle katılıyorum**
1. Öğrencilerin sınıf içi performanslarını nasıl değerlendireceğimi biliyorum.	1	2	3	4	5	6
2. Ders anlatımımı öğrencilerin anladıkları veya anlamadıkları konulara göre uyarlayabilirim.	1	2	3	4	5	6
3. Öğretim yöntemimi farklı öğrenme seviyelerindeki öğrencilere göre düzenleyebilirim.	1	2	3	4	5	6
4. Öğrenmeyi zenginleştirmek için etkili kaynak ve etkinlik seçebilirim.	1	2	3	4	5	6
5. Derslerimde çeşitli öğretim yöntemlerini kullanabilirim.	1	2	3	4	5	6
6. Ders anlatırken sınıfıma etkili bir şekilde hakim olabilirim.	1	2	3	4	5	6
7. Farklı ölçme yöntem ve tekniklerini etkili bir şekilde kullanabilirim.	1	2	3	4	5	6

8. Bireysel farklılıkları göz önüne alarak bir dersi planlayabilirim.	1	2	3	4	5	6
9. Bilgisayarda çalışırken karşılaştığım teknik bir sorunu nasıl giderebileceğimi biliyorum.	1	2	3	4	5	6
10. Temel bilgisayar donanım parçalarını (Ekran Kartı, Anakart, Ana Bellek, RAM vb.) ve işlevlerini biliyorum.	1	2	3	4	5	6
11. Temel bilgisayar yazılımlarını (Windows, Office, Powerpoint, Media Player vb.) kullanabilirim.	1	2	3	4	5	6
12. Sunum araçlarını (projeksiyon cihazı, akıllı tahta, tepegöz vb.) etkin bir şekilde kullanabilirim.	1	2	3	4	5	6
13. Yeni karşılaştığım teknolojileri (donanım veya yazılım) kullanmayı kolaylıkla öğrenebilirim.	1	2	3	4	5	6
14. Aradığım görsel ve işitsel teknolojileri (animasyon, simülasyon vb.) kolaylıkla bulabilirim (internet yoluya, satın alarak vb.).	1	2	3	4	5	6
15. Bilgisayarda ortaya çıkan yazılımsal bir sorunu kolaylıkla çözebilirim.	1	2	3	4	5	6
16. Öğretim yönteminin etkili olmasını sağlayacak teknolojiler seçebilirim.	1	2	3	4	5	6
17. Derslerimde kullanacağım öğretim yöntemime uygun teknolojileri (donanım veya yazılım) belirleyebilirim.	1	2	3	4	5	6
18. Derslerimde teknolojinin kullanıldığı etkinlikler oluşturabilirim.	1	2	3	4	5	6
19. Dersin içeriğini zenginleştirecek teknolojiler seçebilirim.	1	2	3	4	5	6
20. Öğretmen olduğumda teknolojiyi kullanırken sınıfı rahatlıkla kontrol edebilirim.	1	2	3	4	5	6
21. Yeni bir teknolojinin eğitim-öğretimde kullanılabilirliğini değerlendirebilirim.	1	2	3	4	5	6
22. Teknolojiden etkili bir şekilde yararlanmamı sağlayacak şekilde dersimi planlayabilirim.	1	2	3	4	5	6
23. İlköğretim matematik öğretim programındaki geometri konularıyla ilgili (geometrik cisimler, çokgenler, çember, örüntü ve süslemeler vb.) yeterli bilgiye sahibim.	1	2	3	4	5	6
24. İlköğretim matematik öğretim programındaki geometri konularıyla ilgili soruları kolaylıkla cevaplayabilirim.	1	2	3	4	5	6
25. İlköğretim matematik öğretim programındaki geometri konularını günlük yaşamla ilişkilendirebilirim.	1	2	3	4	5	6
26. Geometri konularını matematiğin diğer öğrenme alanlarıyla ve farklı disiplinlerle (Türkçe, Sosyal Bilgiler vb.) ilişkilendirebilirim.	1	2	3	4	5	6
27. Geometri konularında kendimi geliştirmek için araştırmalar yapabilirim.	1	2	3	4	5	6
28. İlköğretim programında yer alan geometri konularındaki	1	2	3	4	5	6

matematiksel kavramları (doğru, nokta, açı kavramı vb.) açıklayabilirim.						
29. İlköğretim programında yer alan geometri konularındaki ispatları yapabilirim.	1	2	3	4	5	6
30. Öğrencilerin geometri konularını öğrenme süreçlerine yardımcı olacak etkili öğretim yöntemlerini seçebilirim.	1	2	3	4	5	6
31. Öğrencilerin geometri konularındaki kavram yanılgılarını belirleyebilirim.	1	2	3	4	5	6
32. Geometriyi öğretirken çeşitli öğretim yöntemlerini (problem çözme, vb.) kolaylıkla kullanabilirim.	1	2	3	4	5	6
33. Öğrencilerin geometri konularıyla ilgili kavram yanılgılarının nedenlerini belirleyebilirim.	1	2	3	4	5	6
34. Öğrencilerin geometri konularındaki öğrenme düzeylerini belirleyebilirim.	1	2	3	4	5	6
35. Geometriyle ilgili öğrencileri öğrenmeye güdüleyebilecek bir ders planlayabilirim.	1	2	3	4	5	6
36. Öğretmen olduğumda ders anlatırken geometriyi diğer matematik konularıyla ilişkilendirebilirim.	1	2	3	4	5	6
37. Öğrencilerin ihtiyaçlarını göz önüne alarak geometriyle ilgili etkinlikler hazırlayabilirim.	1	2	3	4	5	6
38. Geometride hangi tür teknolojilerin (bilgisayar, yazılım, materyal vb.) kullanıldığını biliyorum.	1	2	3	4	5	6
39. Geometri konularında hangi bilgisayar yazılımlarının (Geometer's Sketchpad, Logo, Geogebra, C.A.R. vb) olduğunu biliyorum.	1	2	3	4	5	6
40. Hangi donanımsal teknolojilerin (projeksiyon cihazı, hesap makinesi, akıllı tahta vb.) geometri konularında kullanılabileceğini biliyorum.	1	2	3	4	5	6
41. Geometriyi öğretirken teknolojiyi ve öğretim yöntemimi etkili bir şekilde bir araya getirebilirim.	1	2	3	4	5	6
42. Geometri dersinde öğrencilerin öğrenimini ve öğretimimi zenginleştirecek teknolojiler seçebilirim.	1	2	3	4	5	6
43. Diğer öğretmenlerin geometri öğretiminde, teknolojiyi ve öğretim yöntemlerini bir araya getirmelerine yardımcı olabilirim.	1	2	3	4	5	6
44. Teknolojiyi ve farklı öğretim yöntemlerini kullanarak geometri konularını etkili bir şekilde anlatabilirim.	1	2	3	4	5	6
45. Görsel ve işitsel teknolojileri (animasyon, simülasyon vb.) geometri öğretirken kolaylıkla kullanabilirim.	1	2	3	4	5	6
46. Geometri öğretiminde teknoloji kullanırken öğrencilerin karşılaştığı bir sorunu (donanımsal veya yazılımsal) rahatlıkla çözebilirim.	1	2	3	4	5	6
47. Teknolojiyi ve öğretim yöntemimi etkili bir biçimde bir araya getirerek geometri dersimi planlayabilirim.	1	2	3	4	5	6

48. Dinamik geometri ve matematik yazılımlarını (Geometer's Sketchpad, Geogebra, Cabri, vb.) nasıl etkili kullanabileceğimi biliyorum.	1	2	3	4	5	6
49. Dinamik geometri ve matematik yazılımlarını kullanırken bir sorunla karşılaştığımda nasıl çözeceğimi biliyorum.	1	2	3	4	5	6
50. Geometri konularını öğretmek için dinamik geometri ve matematik yazılımlarını kullanabilirim.	1	2	3	4	5	6
51. Geometriyi dinamik geometri ve matematik yazılımları ile öğretirken öğrencilerin öğrenme düzeylerini etkili bir şekilde değerlendirebilirim.	1	2	3	4	5	6

Kişisel Bilgiler

1. Cinsiyetiniz : ☐ Bay ☐ Bayan

2. Sınıfınız : ☐ 3. Sınıf ☐ 4. Sınıf

3. Lütfen aldığınız dersleri işaretleyiniz *(Birden fazla seçenek işaretleyebilirsiniz. Halen almakta olduğunuz dersleri de dikkate alınız.)* :

☐ Özel Öğretim Yöntemleri I ☐ Okul Deneyimi

☐ Özel Öğretim Yöntemleri II ☐ Öğretmenlik Uygulaması

4. Matematik eğitiminde teknoloji kullanımıyla ilgili hangi ders(leri) aldınız?

____

5. Öğretmenlik deneyiminiz var mı? (Okullar, Dersaneler, Özel ders vb.) ☐Evet ☐Hayır

6. İleride teknolojiyi derslerinizde ne kadar sıklıkla kullanmayı planlıyorsunuz?

☐ Hiçbir zaman ☐ Nadiren ☐ Bazen ☐ Sıklıkla ☐ Her zaman

7. Eğer ileride sınıflarınızda istediğiniz teknolojilere ulaşma imkânınız olursa, geometriyi öğretirken hangi teknolojileri kullanmayı planladığınızı kısaca nedenleriyle birlikte açıklayınız.

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APPENDIX C

Pattern Matrix from Factor Analysis

Pattern Matrix

	Factor						
	F_1	F_2	F_3	F_4	F_5	F_6	F_7
TPCK - item 45	,719						
TPCK - item 44	,674						
TPCK - item 48	,665						
TPCK - item 46	,657						
TPCK - item 47	,641						
TCK - item 42	,507	-,257		,316			
TPCK - item 50	,469	-,234					
TCK - item 43	,465			,265			
PCK - item 39	,301			-,236		-,262	
TPCK - item 53		-,924					
TCK - item 51		-,866					
TPCK - item 54		-,823					
TCK - item 52		-,821					
TCK - item 41		-,686					
TCK - item 40	,227	-,340				-,229	
TPK - item 18			-,897				
TPK - item 19			-,879				
TPK - item 17			-,738				
TPK - item 16			-,606				
TPK - item 23			-,466				,208
TPK - item 22			-,255	,212			,220
TK - item 7				,702			
TK - item 1				,675			
TK - item 5				,609			
TK - item 6	,288			,547			-,240
TK - item 2				,516			
TK - item 4				,379	-,243		
TPCK - item 49		-,340		,353			
PK - item 8					-,734		

Continued / 1

PK - item 9					-,671	-,230	
PK - item 10					-,651		
PK - item 12			-,296		-,500		
PK - item 15					-,476		,230
PK - item 13					-,415		
PK - item 14					-,402		
TPK - item 21					-,371		,286
PK - item 11			-,345		-,359	-,228	
TPK - item 20			-,242		-,278		,259
CK - item 25						-,732	
CK - item 26						-,602	
CK - item 30						-,567	
CK - item 24						-,559	
CK - item 29						-,533	
CK - item 27	,317					-,399	
PCK - item 37	,227					-,395	,236
TK - item 3				,366		-,375	
PCK - item 31					-,213	-,357	,337
PCK - item 38	,277					-,336	,202
PCK - item 36	,206					-,334	,295
CK - item 28						-,311	,302
PCK - item 34							,764
PCK - item 32							,636
PCK - item 35							,589
PCK - item 33	,287						,482

Extraction Method: Maximum Likelihood.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 15 iterations.
b. Factor labels:

F_1 Technological Pedagogical Content Knowledge (TPACK)
F_2 Technological Content Knowledge (TCK)
F_3 Technological Pedagogical Knowledge (TPK)
F_4 Technology Knowledge (TK)
F_5 Pedagogical Knowledge (PK)
F_6 Content Knowledge (CK)
F_7 Pedagogical Content Knowledge (PCK)

APPENDIX D

Statistical Results and Graphs from Preliminary Analyses of TPACK Dimensions

Descriptives

			Statistic	Std. Error
PK	Mean		4,5982	,02148
	95% Confidence Interval for Mean	Lower Bound	4,5560	
		Upper Bound	4,6404	
	5% Trimmed Mean		4,6199	
	Std. Deviation		,59982	
	Skewness		-,847	,088
	Kurtosis		2,757	,175
TK	Mean		4,1872	,03440
	95% Confidence Interval for Mean	Lower Bound	4,1197	
		Upper Bound	4,2547	
	5% Trimmed Mean		4,2130	
	Std. Deviation		,96073	
	Skewness		-,379	,088
	Kurtosis		-,134	,175
CK	Mean		4,8214	,02454
	95% Confidence Interval for Mean	Lower Bound	4,7732	
		Upper Bound	4,8696	
	5% Trimmed Mean		4,8500	
	Std. Deviation		,68532	
	Skewness		-,745	,088
	Kurtosis		1,642	,175
PCK	Mean		4,7480	,02287
	95% Confidence Interval for Mean	Lower Bound	4,7031	
		Upper Bound	4,7929	
	5% Trimmed Mean		4,7715	
	Std. Deviation		,63877	
	Skewness		-,908	,088
	Kurtosis		2,701	,175
TPK	Mean		4,4274	,02726
	95% Confidence Interval for	Lower Bound	4,3738	

	Mean	Upper Bound	4,4809	
	5% Trimmed Mean		4,4588	
	Std. Deviation		,76119	
	Skewness		-,730	,088
	Kurtosis		,844	,175
TCK	Mean		3,7202	,03866
	95% Confidence Interval for	Lower Bound	3,6443	
	Mean	Upper Bound	3,7961	
	5% Trimmed Mean		3,7354	
	Std. Deviation		1,07963	
	Skewness		-,263	,088
	Kurtosis		-,601	,175
TPCK	Mean		4,2698	,03096
	95% Confidence Interval for	Lower Bound	4,2090	
	Mean	Upper Bound	4,3306	
	5% Trimmed Mean		4,3037	
	Std. Deviation		,86471	
	Skewness		-,653	,088
	Kurtosis		,394	,175

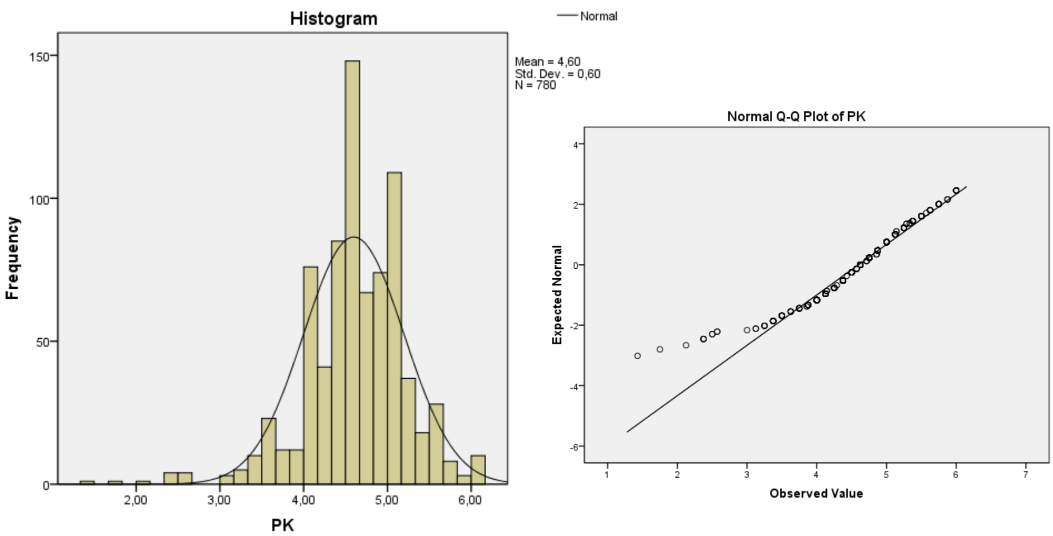


Figure 6 Histogram and Q-Q plot of Pedagogical Knowledge

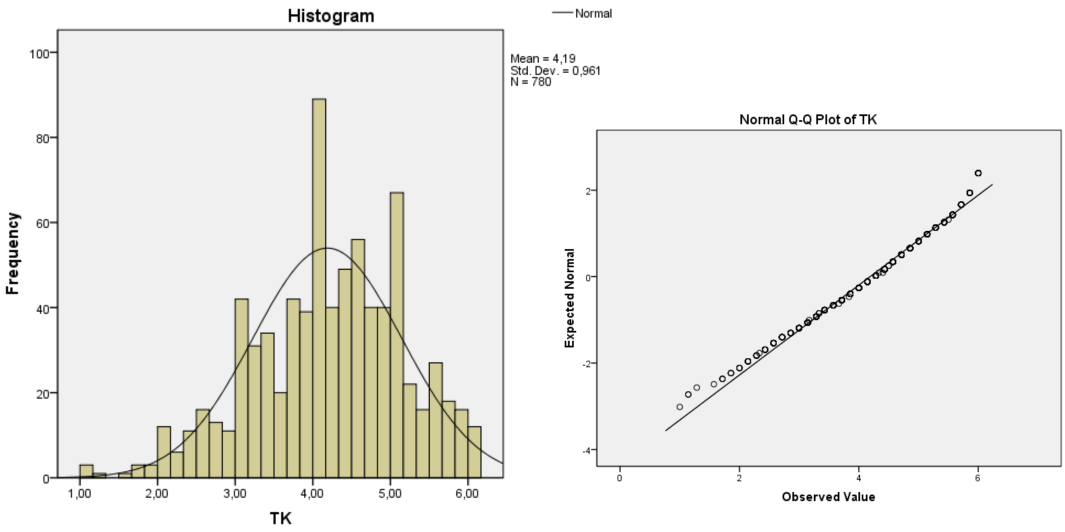


Figure 7 Histogram and Q-Q plot of Technological Knowledge

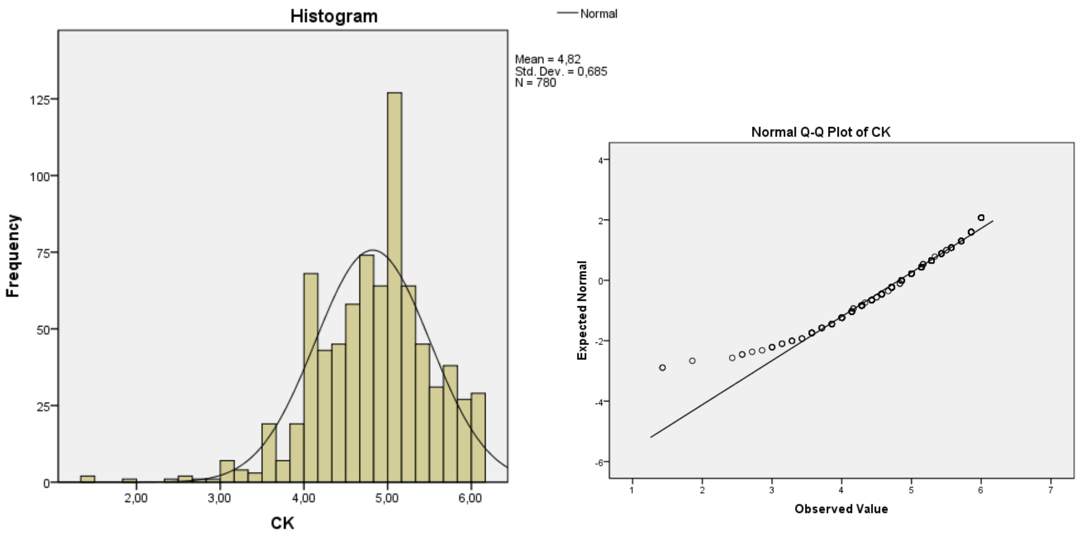


Figure 8 Histogram and Q-Q plot of Content Knowledge

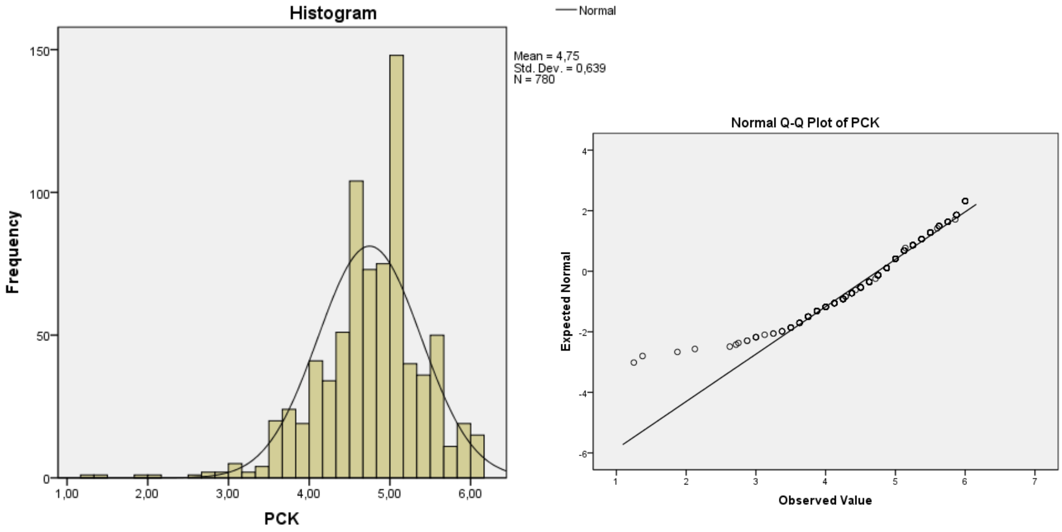


Figure 9 Histogram and Q-Q plot of Pedagogical Content Knowledge

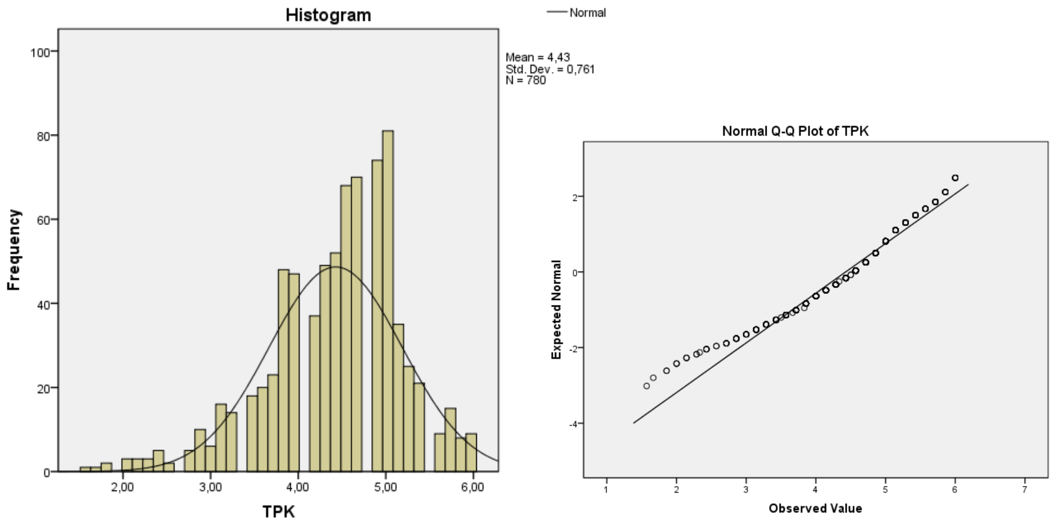


Figure 10 Histogram and Q-Q plot of Technological Pedagogical Knowledge

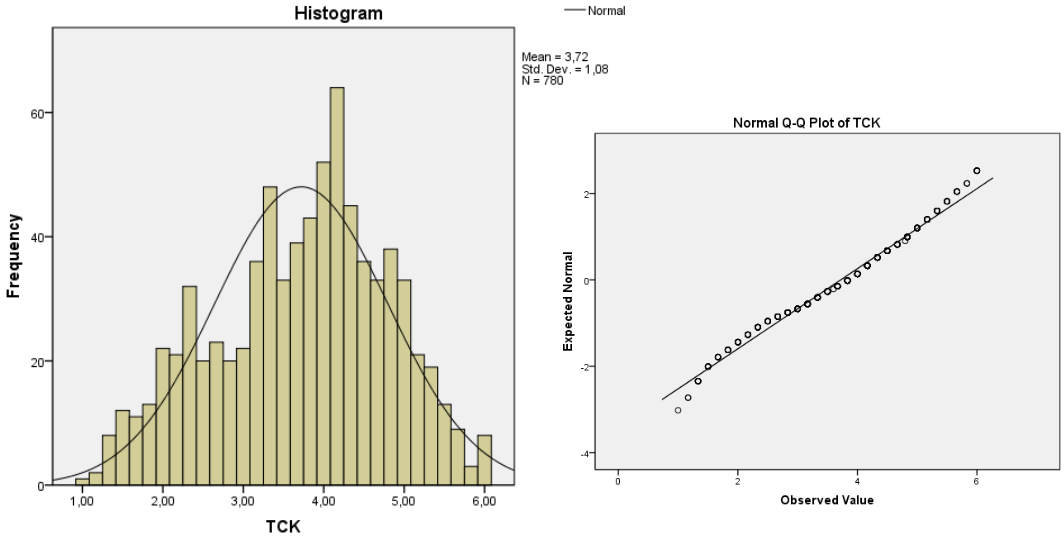


Figure 11 Histogram and Q-Q plot of Technological Content Knowledge

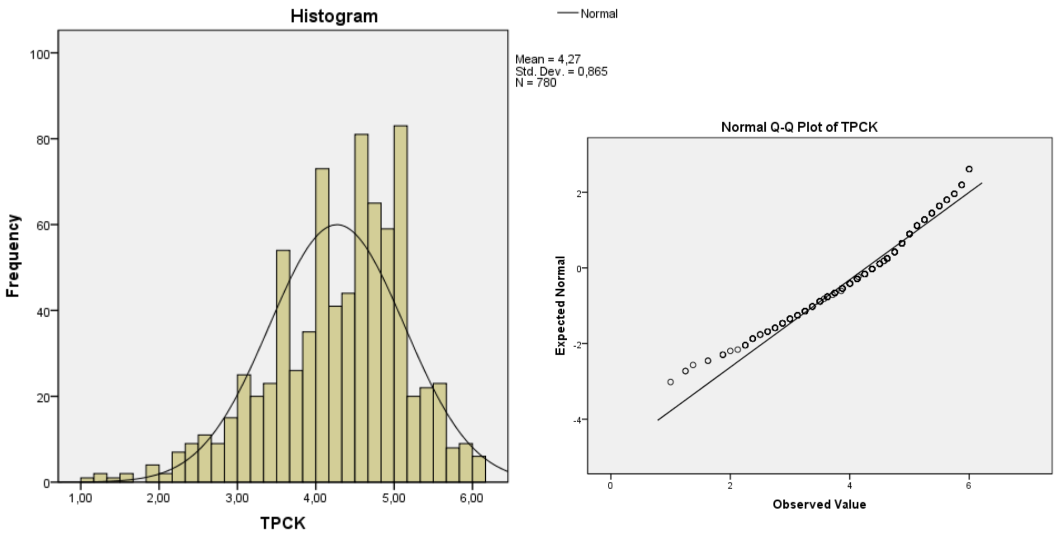


Figure 12 Histogram and Q-Q plot of Technological Pedagogical Content Knowledge

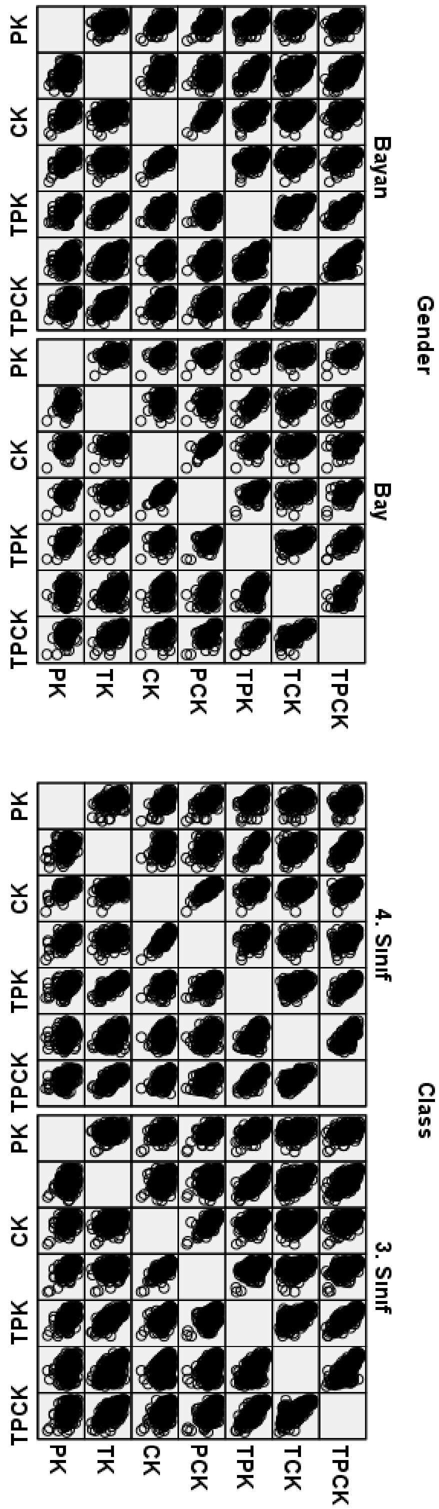
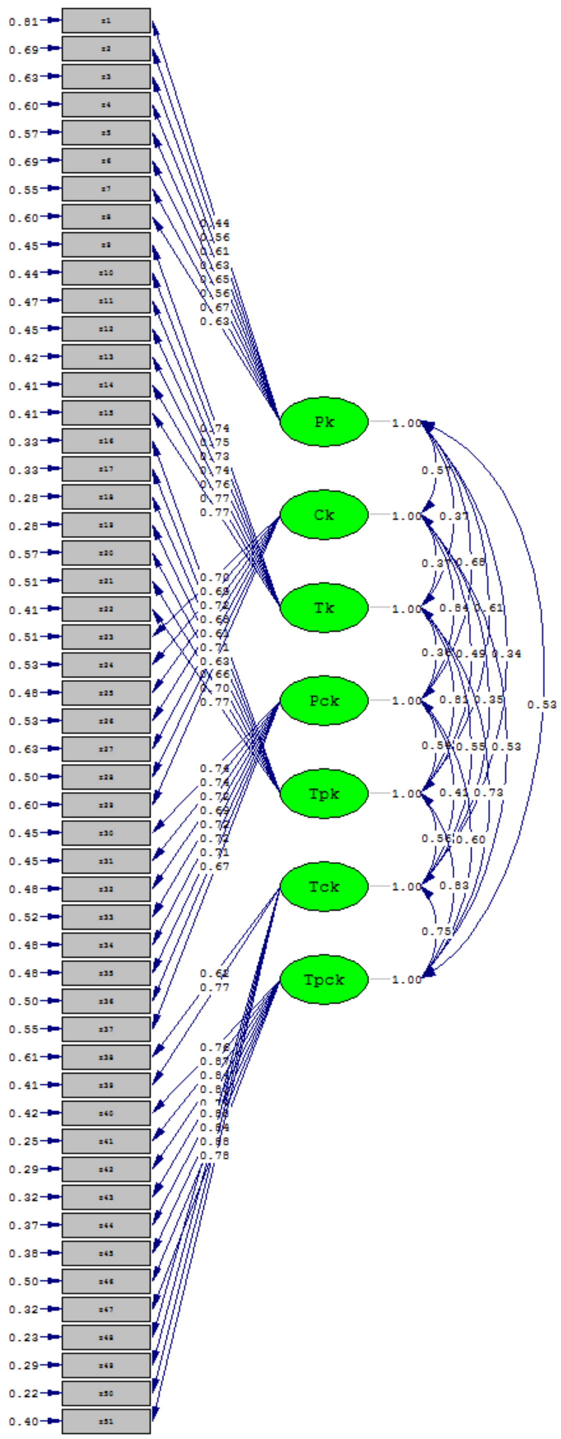


Figure 13 Scatter Plots of Dimensions of Technological Pedagogical Content Knowledge

APPENDIX E

Path Diagram of LISREL



APPENDIX F

TEZ FOTOKOPİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü ☐

Sosyal Bilimler Enstitüsü ☒

Uygulamalı Matematik Enstitüsü ☐

Enformatik Enstitüsü ☐

Deniz Bilimleri Enstitüsü ☐

YAZARIN

Soyadı : BULUT

Adı : AYKUT

Bölümü : İLKÖĞRETİM FEN VE MATEMATİK EĞİTİMİ

TEZİN ADI (İngilizce) : INVESTIGATING PERCEPTIONS OF PRESERVICE MATHEMATICS TEACHERS ON THEIR TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK) REGARDING GEOMETRY

TEZİN TÜRÜ : Yüksek Lisans ☒ Doktora ☐

1. Tezimin tamamı dünya çapında erişime açılsın ve kaynak gösterilmek şartıyla tezimin bir kısmı veya tamamının fotokopisi alınsın. ☐
2. Tezimin tamamı yalnızca Orta Doğu Teknik Üniversitesi kullancılarının erişimine açılsın. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) ☐
3. Tezim bir (1) yıl süreyle erişime kapalı olsun. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) ☒

Yazarın imzası .... Tarih ....