PROMOTING AND INVESTIGATING PRE-SERVICE MIDDLE SCHOOL MATHEMATICS TEACHERS' TPACK-PRACTICAL DEVELOPMENT IN THE CONTEXT OF AN UNDERGRADUATE COURSE

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ABSTRACT

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The purpose of the study was to enhance and investigate the technological pedagogical content knowledge-practical (TPACK-P) development of pre-service middle school mathematics teachers (PMTs) through the Technology Use in Mathematics Education (TUME) course aiming TPACK-P development in three pedagogical domains: Assessment, Planning and Design, and Enactment. TUME course was designed and implemented based on four principles driven from the TPACK and TPACK-P frameworks which were transformative approach, collaborative learning, activity-supported learning, and practice-based learning. Following the single case study methodology, TPACK-P levels of 11 PMTs were determined from pre-questionnaires, initial and final technology-integrated lesson plans, observations, researcher's field notes, micro-teaching, peer and self-assessments, and semi-structured post-interviews. PMTs' beginning TPACK-P in

Assessment domain and Planning and Design domain was detected at level 1, the Lack of Use Level. PMTs’ TPACK-P levels increased from level 1 to higher levels in all three domains. According the their TPACK-P developments, PMTs were placed in three groups which were Mostly Simple Adoption Group, Mostly Infusive Application Group, and Mostly Reflective Application Group corresponding to levels 2, 3, and 4, respectively. Findings showed that the TUME course was effective in promoting PMTs’ TPACK-P development. Participants’ knowledge and practices in each group were narrated to provide a holistic picture of their progress and TPACK-P levels. The principles, design, and implementation details of practice-based and content-specific the TUME course were explicitly reported for researchers to be able to implement the course in teacher education programs to develop and assess PMTs’ TPACK-P.

Keywords: Mathematics Education, Pre-service Middle School Mathematics Teachers, Teacher Education, Technology, TPACK, TPACK-Practical

ÖZ

ORTAOKUL MATEMATİK ÖĞRETMEN ADAYLARININ TPAB-PRATİK GELİŞİMLERİNİN BİR LİSANS DERSİ KAPSAMINDA DESTEKLENMESİ VE İNCELENMESİ

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Bu çalışmanın amacı, Değerlendirme, Planlama ve Tasarım ve Uygulama olmak üzere üç pedagojik alanda TPAB-P gelişimini hedefleyen Matematik Eğitiminde Teknoloji Kullanımı (METK) dersinde ortaokul matematik öğretmen adaylarının (OMÖA) teknolojik pedagojik alan bilgisi-pratik (TPAB-P) gelişimini desteklemek ve incelemektir. METK dersi, TPAB ve TPAB-P teorik çerçevelerinden yola çıkarak belirlenmiş dönüşümcü yaklaşım, işbirlikli öğrenme, etkinlik destekli öğrenme ve uygulamaya dayalı öğrenme olmak üzere dört ilkeyi temel alarak planlanmış ve uygulanmıştır. Tek durum çalışması deseni kullanılarak 11 OMÖA'nın TPAB-P seviyeleri ön testler, teknoloji entegre edilmiş ön ve son ders planları, gözlemler, araştırmacının saha notları, mikro öğretim, akran ve öz değerlendirmeler ve yarı-yapılandırılmış görüşmelerden elde edilen veri ile belirlenmiştir. OMÖA'nın başlangıç TPAB-P seviyelerinin Değerlendirme alanı ve Planlama ve Tasarım alanında 1. seviye olan Kullanım Eksikliği Seviyesinde olduğu tespit edilmiştir. OMÖA'nın TPAB-P seviyeleri her üç alanda da 1. seviyeden daha yüksek seviyelere yükselmiştir. OMÖA'ları TPAB-P gelişimlerine göre, Çoğunlukla Basit Benimseme Grubu, Çoğunlukla Kaynaştırıcı Uygulama Grubu ve Çoğunlukla Yansıtıcı Uygulama Grubu olan ve sırasıyla 2, 3 ve 4 seviyelerine karşılık gelen üç gruba yerleştirilmiştir. Bulgular, METK dersinin OMÖA'larının TPAB-P gelişimini artırmada etkili olduğunu göstermiştir. Katılımcıların gelişimlerinin ve TPAB-P düzeylerinin bütünsel bir resmini sunmak için her gruptaki katılımcıların bilgileri ve uygulamaları ayrıntılı olarak açıklanmıştır. Araştırmacıların OMÖA'larının TPAB-P gelişimini artırmak ve incelemek amacıyla öğretmen eğitimi programlarında METK dersini verebilmeleri için uygulama temelli ve alana özgü olan METK dersinin prensipleri, tasarımı ve uygulama detayları açık bir şekilde anlatılmıştır.

Anahtar Kelimeler: Matematik Eğitimi, Ortaokul Matematik Öğretmen Adayları, Öğretmen Eğitimi, Teknoloji, TPAB, TPAB-Pratik

To Education

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LIST OF ABBREVIATIONS

AMTE	Association of Mathematics Teacher Educators
EME	Elementary Mathematics Education
FATIH	The Movement of Enhancing Opportunities and Improving Technology
ICT	Information and Communication Technologies
ISTE	International Society for Technology in Education
MoNE	Ministry of National Education
NCTM	National Council of Teachers of Mathematics
PCK	Pedagogical Content Knowledge
PMT	Pre-service Middle School Mathematics Teacher
PT	Pre-service Teacher
TPACK	Technological Pedagogical Content Knowledge
TPACK-P	Technological Pedagogical Content Knowledge – Practical
TUME	Technology Use in Mathematics Education

CHAPTER 1

INTRODUCTION

Teaching is a difficult and ill-structured process, and technology integration adds upon the difficulties of the process (Graham, Borup, & Smith, 2012). Hence, teaching with technology is a "wicked problem" (Rittel & Webber, 1973, p. 160). Effective utilization of technology in education is highly expected (Kaufman, 2015) which brings another challenge. Such a challenge can be solved effectively which requires teachers to be equipped with necessary knowledge and experience about how to utilize technology in teaching (Akbaba-Altun, 2006; Cakiroglu & Haser, 2002). Yet, some teachers have been rather late to utilize technologies in classrooms and fall behind meeting the needs of 21st century mathematics classrooms for all learners (Kavanoz, Yuksel, & Ozcan, 2015; Zelkowski, 2011c). Moreover, many teachers are not familiar with digital technologies and they meet students who are native to these technologies in classrooms (Prensky, 2001). Knowing only the facilities of technologies is not adequate for adopting them for instruction (Angeli & Valanides, 2009; Mishra, Koehler, & Kereluik, 2009). Teachers need to know how to benefit from the opportunities that technology provides for designing lessons which help students to understand the content meaningfully (Lee & Hollebrands, 2008). They also need to progress in designing and implementing technology enhanced effective courses in line with curriculum goals and standards (Lawless & Pellegrino, 2007).

Education in the 21st century demands teachers who possess "sound technical skills that keep pace with real-world, everyday use of technology and that reinforce content knowledge" (Kaufman, 2015, p. 8). Among the recent educational standards, International Society for Technology in Education (ISTE, 2017) proposed standards for educators many of which were about digital competencies. Among these, under the leader characteristic, teachers are expected to “advocate for equitable access to educational technology, digital content and learning opportunities to meet the diverse needs of all students, and model for colleagues the identification, exploration, evaluation, curation and adoption of new digital resources and tools for learning” (ISTE, 2017, p. 1). Teachers are expected to “design authentic learning activities that align with content area standards and use digital tools and resources to maximize active, deep learning, and explore and apply instructional design principles to create innovative digital learning environments that engage and support learning” (ISTE, 2017, p. 2). Therefore, they need to have competencies as asserted more explicitly in ISTE (2008) in four teacher actions:

> (1) design or adapt relevant learning experiences that incorporate digital tools and resources to promote student learning and creativity,
> (2) develop technology-enriched learning environments that enable all students to pursue their individual curiosities and become active participants in setting their own educational goals, managing their own learning, and assessing their own progress,
> (3) customize and personalize learning activities to address students’ diverse learning styles, working strategies, and abilities using digital tools and resources,
> (4) provide students with multiple and varied formative and summative assessments aligned with content and technology standards, and use resulting data to inform learning and teaching. (p. 1)

Turkish Ministry of National Education (MoNE) recommends technology integration into mathematics in the middle school (5^{th}, 6^{th}, 7^{th}, and 8^{th} grades) mathematics curriculum (MoNE, 2013). It is suggested among the general aims of the curriculum that teachers use technology effectively in the teaching and learning process. In order to achieve this goal, teachers need to possess the basic skills to use technology and adapt technological tools with the appropriate pedagogy to teach mathematics content (MoNE, 2013). Similarly, National Council of Teachers of Mathematics (NCTM) in the United States indicates that technology is essential for effective teaching and learning of mathematics (NCTM, 2014) and Association of Mathematics Teacher Educators (AMTE) emphasizes the role of technology in identifying and meeting diverse student needs (AMTE, 2009).

There has been an increasing tendency to enhance the use of educational technology in Turkey, as exemplified by the Movement of Enhancing Opportunities and Improving Technology (Fırsatları Artırma Teknolojiyi İyileştirme Hareketi) (FATIH) project which has been carried out by the MoNE, aiming to enhance teaching quality by integrating technology and pedagogy in order to enable equal opportunities for all students. Specifically, this project aimed to encourage teachers to use educational technology, inspire students' creative thinking ability, share technological resources with students, and ensure that students have technological learning opportunities (FATIH, 2018). As a result, each teacher is expected to be competent to effectively apply educational technology in their curriculum designs, practice, classroom management, and assessment.

Koehler and Mishra (2006) presented Technological Pedagogical Content Knowledge (TPACK) as a framework for teacher knowledge of technology integration into education which is formed by the complex interaction between three bodies of knowledge: Technology, Pedagogy, and Content. The knowledge constructs in the framework can be investigated separately. However, in practice they are embedded and cannot be separated (Angeli & Valanides, 2005, 2009). TPACK is a unified body of knowledge which is developed for using technology in teaching (Koehler & Mishra, 2008; Mishra & Koehler, 2006) and goes beyond the knowledge constructs it includes (Angeli & Valanides, 2009, 2015; Koehler & Mishra, 2009; Thompson & Mishra, 2007; Yeh, Hsu, Wu, Hwang, & Lin, 2014). From this view, TPACK is the knowledge of context, student needs, pedagogy, tool affordances, content (Angeli & Valanides, 2009), and knowledge about and application of technology integration to enhance students' learning and teachers' instruction (Jen, Yeh, Hsu, Wu, & Chen, 2016). Throughout the TPACK development process, teachers build connections between pedagogical approaches appropriate for a specific content that is supported by technology.

TPACK is a fruitful framework that empowers potential for new approaches derived from it (Hewitt, 2008). Researchers proposed other models that were adopted and derived from the epistemology of TPACK framework each of which grows upon a construct that the framework comprises (see Chapter III). Among these, TPACK Practical (TPACK-P) framework (i.e., Yeh, Hsu, Wu, et al., 2014) is distinctive from the other models of TPACK since it was driven from both knowledge- and practice-based nature of TPACK and emphasized content-specific development of TPACK. In addition, TPACK-P is a two dimensional framework that serves for identifying TPACK proficiencies belonging to three pedagogical domains which are assessment, designing and planning, and enactment (Yeh, Lin, Hsu, Wu, & Hwang, 2015).

Teachers need to experience designing technology-integrated concrete activities through their teacher education program before they practice in the field since the teacher education programs have great influence on graduate teachers' technology integration in their instructions (Tondeur, Roblin, van Braak, Voogt, & Prestridge, 2017; Tondeur, Scherer, Siddiq, & Baran; 2017). However, it has been a challenging and debated issue to fulfill this aim in teacher education programs (Niess, 2011) which was explicitly stated as follows:

> "The main issue emerging seems to be the lack of relationship between what beginning teachers learned in their pre-service education and what is needed in order to make progress in using technology in the classroom. Therefore, teacher education institutions need to actively help future teachers to make the link between technology, pedagogy and content knowledge in all aspects of their education and fieldwork" (Tondeur, Roblin, et al., 2017, p. 175).

Therefore, teacher education programs need a reform to improve course contents (Koehler, Mishra, & Yahya, 2007; Niess, 2006) in order to provide pre-service teachers (PTs) with content-specific and pedagogy-related experiences of technology integration (Tondeur, Roblin, et al., 2017) blended with curriculum goals (Agyei & Voogt, 2011a). Utilization of TPACK framework is suggested to transform teacher education programs to prepare PTs who are competent in effective technology integration to education (Koehler & Mishra, 2009) and to design fruitful environments which support PTs to gain experiences about technology integration (Agyei & Voogt, 2012). The framework aims at preparing PTs who are skillful in effective integration of technology to teach a specific content to a specific group (Tondeur et al., 2012).

Recently, there has been a considerable increase in the amount of research about developing and evaluating PTs' TPACK in mathematics education within teacher education course contexts through different time intervals. TPACK framework and the other models were used as the base for designing courses that aim at developing PTs' technology integration competencies, thereby their TPACK. Researchers either integrated technology to the existing teacher education courses such as content courses (e.g., Meagher et al., 2011), methods courses (e.g., Lee & Hollebrands, 2008; Meng & Sam, 2013), teaching practice courses (Agyei & Voogt, 2012; Balgalmis, 2013) or designed and implemented new courses (e.g., Akyuz, 2016). Besides, several strategies were utilized to develop and assess PTs' TPACK in these courses. Linking theory with practice, learning technology integration by designing, the teacher educator being the role model, and working collaboratively with peers were among the characteristics of effective interventions of teacher education programs for preparing PTs sufficiently competent in integrating technology effectively in their teaching practices (Tondeur et al., 2012).

1.1 Statement of the Purpose and the Research Question

The main purpose of the present study was to enhance and investigate TPACK-P development of pre-service middle school mathematics teachers (PMTs). To serve this aim, the Technology Use in Mathematics Education Course (TUME) was designed and implemented based on the TPACK-P framework. The study was conducted to answer the following research question and the sub-questions:

1. How does the Technology Use in Mathematics Education Course influence pre-service middle school mathematics teachers' TPACK-P development?
    a) What are pre-service middle school mathematics teachers' TPACK-P proficiency levels in the beginning of the Technology Use in Mathematics Education Course?
    b) What are pre-service middle school mathematics teachers' TPACK-P proficiency levels at the end of the Technology Use in Mathematics Education Course?

1.2 Significance of the Study

Middle school mathematics education curriculum consists of five learning areas; numbers and operations, algebra, geometry and measurement, data processing, and probability (MoNE, 2013). In the curriculum, the use of Information and Communication Technologies (ICT) is recommended in three of these five learning areas which are algebra, geometry and measurement, and data processing learning areas. As it is not specifically mentioned in the curriculum, the selection and integration of the technology to be used in teaching mathematics is left to teachers. Therefore, teacher education programs have a crucial role and responsibility for preparing future teachers who are competent in technology integration in education (Hofer & Grandgenett, 2012; Niess, 2005; Yeh, Hsu, Wu, et al., 2014) and for helping them to enhance mathematics teaching with digital technologies of 21st century (Niess, 2012). In order to enhance pre-service teachers' TPACK proficiency, teacher training programs should introduce them with ICTs (Zelkowski, 2011a), enable them to discover utilizations of ICTs in practice, and guide them to design and implement ICT integrated lessons (Ay, Karadag, & Acat, 2016). Because, when pre-service teachers develop TPACK integrally, they become prepared for both today's and tomorrow's mathematics classrooms (Lee & Hollebrands, 2008).

Teacher education programs have not completely provided adequate environment and content to enhance PTs' knowledge about and skills of technology integration in practice (Chien, Chang, Yeh, & Chang, 2012), and thereby the development of practical TPACK (Yeh, Lin, Hsu, et al., 2015), which is a broad and complex task to achieve (Aslan & Zhu, 2016; Liu, 2016). The focus of such development attempt should be on how and why PTs integrate technology to teaching (Graham et al., 2012; Yeh, Lin, Hsu, et al., 2015) in order to reveal their reasons for using technology in instruction and to evaluate their TPACK (Yeh, Lin, Hsu, et al., 2015).TPACK is embedded in experience and develops through practice (Yeh, Lin, Hsu, et al., 2015). Therefore, TPACK studies investigating technology use in practice (Voogt, Fisser, Tondeur, & van Braak; 2016) within content-specific domains (Baran & Canbazoglu-Bilici, 2015; Chai, Koh, & Tsai, 2013; Voogt, Fisser, Pareja-Roblin, Tondeur, & van Braak, 2013) are needed. The theoretical basis of the present study was grounded on the practice-based and content-specific nature of TPACK to contribute to the field. Thus, TPACK-P framework, which focused both on knowledge about and application of technology integration in education, was utilized (Yeh, Lin, Hsu, et al., 2015).

Jen et al. (2016) provided exemplary behaviors of science teachers corresponding to the TPACK-P proficiency levels in three domains. In the present study, a different sample provided additional knowledge and behaviors that were general and mathematics content-specific. These were explained in detail in this study. PMTs' knowledge and applications provided exemplary instances corresponding to all of the four TPACK-P proficiency levels in three pedagogical domains. This was a contribution to the TPACK-P framework in terms of providing additional behaviors belonging to its levels and domains in the field of mathematics education. Moreover, the researchers who intend to conduct general or mathematics content-specific TPACK studies could use these knowledge and applications to analyze and validate the findings of their studies.

Niess (2011) suggested that future studies should provide examples of teacher education applications such as courses, programs, or instructional manipulations that ensure development and assessment of PTs' TPACK. In this study, an undergraduate course was designed for developing PMTs' TPACK-P through the course context. The aim was to understand to what extent PMTs develop and demonstrate TPACK-P through the course. This study was unique for comprising distinctive and effective strategies emphasized in the literature within a content-specific course context. Several strategies were emphasized for being effective in enhancing PTs' TPACK development in teacher education courses in the related literature. Four principles were determined based on these effective strategies, the TPACK framework (Mishra & Koehler, 2006) and TPACK-P framework (Yeh, Hsu, Wu, et al., 2014): (1) *transformative approach* (Angeli & Valanides, 2005, 2009; Koehler & Mishra, 2009; Thompson & Mishra, 2007; Yeh, Hsu, Wu, et al., 2014), (2) *collaborative learning* (Agyei & Voogt, 2011a; Jang, 2008b; Koehler et al., 2007; Polly, Mims, Shepherd, & Inan, 2010; Tondeur et al., 2012; Tondeur, Roblin, et al., 2017; Tondeur, Scherer, et al., 2017; Yeh, Lin, Hsu, et al., 2015), (3) *activity-supported learning* (Agyei & Voogt, 2012; Angeli & Valanides, 2009; Harris & Hofer, 2009; Lee & Lee, 2014; Mouza, Karchmer-Klein, Nandakumar, Ozden, & Hu 2014; Yeh, Lin, Hsu, et al., 2015), and (4) *practice-based learning* (Jen et al., 2016; Yeh, Hsu, Wu, et al., 2014). The TUME course was designed and implemented based on these four principles. Another contribution was that the content of the TUME course was broad in terms of technology types and mathematics subjects. Most of the related studies limited the content to one type of technology (e.g., Agyei & Voogt, 2012; Chai et al., 2013; Durdu & Dag, 2017; Kurt, 2016; Meagher et al., 2011; Meng & Sam, 2013; Ozgun-Koca, Meagher, & Edwards, 2010), which limited PTs' content selections and designs; or to a single mathematics subject (e.g., Lee & Hollebrands, 2008), which limited content selections and designs. In the TUME course, the PMTs were introduced with both the general and content-specific technologies and they were free to choose any of these technologies and learning objectives from the five learning areas in the national middle school mathematics curriculum content (i.e., MoNE, 2013) from fifth to eighth grades when designing technology-integrated activities and lessons.

In Turkey, TPACK studies have mostly been conducted by using surveys (Baran & Canbazoglu-Bilici, 2015). The present study was designed and reported following a qualitative approach which provided to make detailed investigation and observation from various perspectives in order to reveal PMTs' TPACK-P development through the course by seeking answers for whys and hows of their knowledge about and application of technology integration to teaching of middle school mathematics subjects. In qualitative studies conducted in Turkey, contexts were not described in detail (Baran & Canbazoglu-Bilici, 2015), which limits the further studies to make comparisons and develop better contexts. The principles, design, and implementation details of the TUME course were explicitly reported which would lead similar courses to be designed and implemented in teacher education programs. The detailed description of the course might gain researchers' attention to rethink about how TPACK-P can be developed through an integrated course. Moreover, the course can be instructed with the same principles in teacher education programs for PTs' TPACK-P development in all areas by utilizing the same principles.

1.3 Definitions of Important Terms

Pedagogical Content Knowledge (PCK): A framework which was proposed by Shulman (1987) referring to "the special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (Shulman, 1987, p. 8).

Technological Pedagogical Content Knowledge (TPACK): A framework which builds on Shulman's (1986, 1987) descriptions of PCK to describe how teachers' understanding of educational technologies and PCK interact with one another to produce effective teaching with technology (Mishra & Koehler, 2006). Among the models that were adopted and derived from the epistemology of TPACK framework, Technological Pedagogical Content Knowledge Practical (TPACK-P) framework (Yeh, Hsu, Wu, et al., 2014) formed the basis of the present research.

Technological Pedagogical Content Knowledge Practical (TPACK-P): TPACK-P is a practice-based and content-specific framework which refers to teachers' knowledge of using ICTs which they "develop from and for their practical teaching" (Yeh, Lin, Hsu, et al., 2015, p. 79). The TPACK-P proficiency is identified in four levels and three pedagogical areas which are assessment, planning and design, and enactment (Jen et al., 2016; Yeh, Lin, Hsu, et al., 2015).

Technology: Mishra and Koehler (2006) defined technology as the "hardware and software such as computers, educational games, and the Internet and the myriad applications supported by it" (p. 1023).

Pre-Service Middle School Mathematics Teachers (PMTs): Fourth year students in their last semester at an Elementary Mathematics Education Program of an Elementary Education Department at a Faculty of Education at a private University located in Ankara, Turkey.

CHAPTER 2

THEORETICAL FRAMEWORK

Technological Pedagogical Content Knowledge (TPACK) framework and Technological Pedagogical Content Knowledge-Practical (TPACK-P) framework which was adopted and derived from the epistemology of TPACK framework were introduced in this chapter. The theoretical roots of TPACK and the generation, validation, and application of TPACK-P framework were explained in detail.

2.1 TPACK Framework

The conceptualization of TPACK was developed from the theoretical framework of Shulman's (1986, 1987) Pedagogical Content Knpwledge (PCK) framework. The PCK is the framework for teacher knowledge about not only differentiated knowledge of a specific content and pedagogical strategies, but also knowing how to teach subject content with appropriate pedagogical strategies in order to meet student needs in the context. For effective teaching, teachers require to be competent in PCK which is "an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1986, p. 8).

The differentiation between content knowledge (CK) and PCK is that CK is teacher knowledge about representations to teach a content, whereas PCK is the knowledge of transforming representations to make content understandable. To be competent in CK, teachers are required to explain knowledge and justification and to know how subjects are related with other subjects and why they are needed in theory and practice (Shulman, 1986).

Shulman (1986) described pedagogical knowledge (PK) as the second type of content knowledge related with teaching dimension of subject matter knowledge. The differentiation between PK and PCK is that teacher knowledge in pedagogy is rather a general type of pedagogical knowledge or a content specific pedagogy. In addition, related with the teachability of the content, PK includes representations and formulations (Shulman, 1986). Shulman (1986) emphasized that since there is no best representation for a specific subject matter, teachers should be equipped with a variety of effective representations which they can obtain from research or produce while teaching. As for teacher knowledge, in addition to the aspects above, knowledge of classroom management strategies, curriculum, learners, learner characteristics, educational contexts, and educational values are included (Shulman, 1986, 1987).

Current reforms in education emphasize the role of technology use in education (National Research Council, 2012). Accordingly, there has been a tendency to integrate knowledge of technology to PCK. In connection to PCK, Mishra and Koehler (2006) proposed TPACK as a framework for teachers' knowledge of technology integration into education as illustrated in Figure 1. Throughout the TPACK development process, teachers build connections between pedagogical approaches appropriate for a specific content that is supported by technology.

In TPACK model, three knowledge domains – Pedagogical Knowledge (PK), Content Knowledge (CK), and Technological Knowledge (TK) – form pairs of knowledge intersections: Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK). These knowledge types and context recognition come together and build TPACK framework which possesses integration of technology into teaching (Koehler & Mishra, 2008).

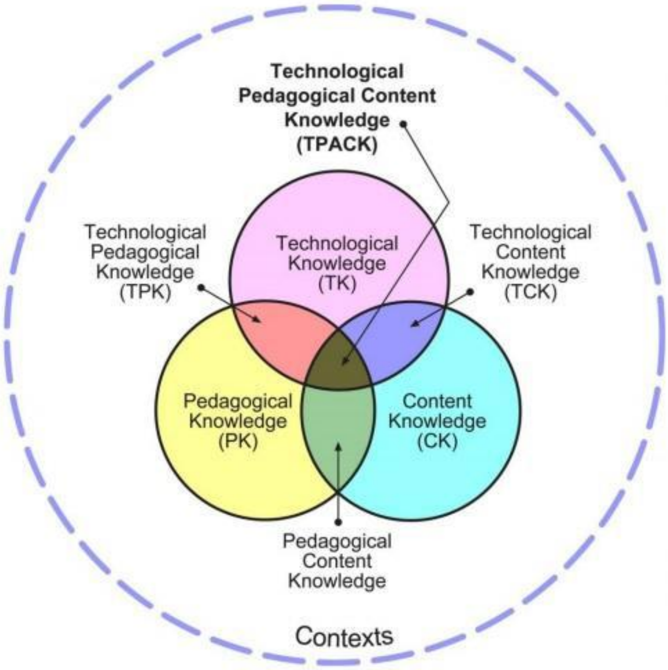


Figure 2.1 Technological Pedagogical Content Knowledge Framework. Reprinted from "What is Technological Pedagogical Content Knowledge?," by M. J. Koehler and P. Mishra, 2009, *Contemporary Issues in Technology and Teacher Education, 9*, p. 63.

CK is subject matter knowledge of teachers which is needed to be learned or taught in teachers' discipline of profession (Koehler & Mishra, 2008; Mishra & Koehler, 2006). CK is, built on Shulman's (1986) definition, teachers' subject matter knowledge, knowledge of the relationship of the content with other concepts and fields, understanding of nature of the knowledge and inquiry, knowledge of facts and theories, and knowledge of evidence and proof (Mishra & Koehler, 2006). PK is the intense knowledge of "the processes and practices or methods of teaching and learning and how it encompasses overall educational purposes, values, and aims" (Mishra & Koehler, 2006, p. 1026). It is a broad knowledge domain including understanding students' diverse learning types and knowledge constructions and knowledge about teaching strategies such as classroom management skills, lesson planning skills, and assessment techniques (Mishra & Koehler, 2006).

PCK is presenting the subject matter understandable to students which is teaching the way the subject matter addresses students' learning characteristics (Shulman, 1986, 1987). Technology was not mentioned and discussed explicitly in PCK framework. Indeed, the role of technology in relation with pedagogy and content was not explained (Angeli & Valanides, 2009), most probably because using technology was not common in teaching at the time of the framework (Mishra & Koehler, 2006). However, Shulman (1986) emphasized that the teachers should be able to employ "the most useful forms of representation of ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations" (p. 9) to represent and formulate the subject matter for students. These features meet what instructional technology provides for students. Mishra and Koehler (2006) combined TK to PCK framework and showed that its affordances in teaching the content through pedagogy are explicit in TPACK framework. In TPACK framework, technology is not limited to digital technologies. Koehler and Mishra (2009) stated that TK is the consistently changing knowledge dimension of TPACK. Yet, many researchers using TPACK framework in their studies refer technology as digital technologies (Angeli & Valanides, 2009; Lee & Tsai, 2010).

Koehler and Mishra (2009) addressed that one should consider the impact of educational technologies on knowledge in various disciplines in order to use and develop them. Using technology provides multiple, effective, and new representations and metaphors to understand concepts which has resulted in profound changes of facts and knowledge in social, applied, and clinical sciences. Therefore, they define TCK as the teachers' knowledge of technologies and decision about the one that best complies with the subject matter.

Teachers' knowledge about affordances and constraints of technological tools affect their pedagogical decisions in designing the courses or the pedagogical strategies can lead to the selection of technology (Mishra & Koehler, 2006). TPK includes the knowledge of kinds of technology available for a particular task and the affordances and constraints of the technologies, knowledge of pedagogical strategies, the ability to select the technology and pedagogical strategy that would serve best to achieve the educational aim, and the ability to match these together (Mishra & Koehler, 2006).

Context is the embracing aspect of the TPACK framework as it is also mentioned visually in Figure 1. In the figure, context covers all knowledge domains in the framework. It affects the interactions between and among the knowledge dimensions. Teachers' reflections of their TPACK into teaching vary according to the diverse classroom contexts where teaching takes place (Koehler & Mishra, 2009).

The knowledge dimensions of TPACK are highlighted briefly above so as to define how the framework occurred and what it is comprised of. However, in the present study, TPACK was used as a unified body of knowledge which is developed for using technology in teaching (Koehler & Mishra, 2008; Mishra & Koehler, 2006). Therefore, to serve the purpose of this study, TPACK was considered as teacher knowledge of technology integration which is a knowledge type different than bringing its seven dimensions together. Taking three knowledge types, CK, PK, and TK, into consideration, one cannot differentiate their existence in practice. Rather, these knowledge types interrelate and constitute a "dynamic equilibrium" (Mishra & Koehler, 2006, p. 1029). In maintaining this equilibrium, teachers need continually to create, fulfill, and reconstruct the needs that occur in their teaching (Koehler & Mishra, 2009).

TPACK framework is a lens for identifying how teachers integrate technology into their lessons (Harris & Hofer, 2009; Hofer & Harris, 2010) and a guide to investigate teachers' instructional decisions (Graham et al., 2012). Shulman (1987) stated that PK and CK surpassed the meanings they referred and formed the elaborated teacher knowledge, which is PCK. Similarly, TPACK denotes more than knowledge of pedagogy, content, and technology (Koehler & Mishra, 2009). Multiple interactions exist among PK, CK, and TK which differ in different contexts. The multiple interactions that take place while teachers make several decisions such as; technology choice and selection of pedagogical strategies suitable for the learning goals while considering the opportunities of the context at the same time results in various implications of technology use in education.

Therefore, teachers' TPACK development is the key for performing effective technology enhanced instructions (Koehler & Mishra, 2009).

Relying on Shulman's PCK definition, TPACK was defined as;

> "the basis of effective teaching with technology, requiring 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 redress 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 to develop new epistemologies or strengthen old ones" (Mishra & Koehler, 2006, p. 1029).

Teachers cannot continue their regular instruction when they use a new technology. Hence, they need to reconstruct the pedagogical techniques, redesign the course content, and reconsider the context of the teaching environment for technology use (Koehler & Mishra, 2009; Mishra & Koehler, 2006). It can be concluded that integrating technology effectively into teaching is difficult and multifaceted due to the nature of teaching where interconnections occur between teachers' TK, PK, CK, and the context in which the teaching takes place.

2.2 Technological Pedagogical Content Knowledge-Practical (TPACK-P) Framework

Technological Pedagogical Content Knowledge-Practical (TPACK-P) (Yeh, Hsu, Wu, et al., 2014) refers to teachers' knowledge of using ICTs which they "develop from and for their practical teaching" (Yeh, Lin, Hsu, et al., 2015, p. 79). Different than other models proposed for TPACK, TPACK-P framework is based on both knowledge and experience (Yeh, Hsu, Wu, et al., 2014). Relying on technology, pedagogy, and content knowledge, TPACK-P framework guides researchers to identify TPACK within teaching contexts. In order to improve and assess teachers' practical knowledge of technology that they need in teaching, TPACK-P proposes a multidimensional framework in which TPACK-P proficiency was determined in four levels and three pedagogical dimensions (Jen et al., 2016). Teachers can practically develop and succeed in planning and performing technology-integrated instructions with the help of TPACK-P framework (Yeh, Hsu, Wu, et al., 2014).

TPACK-P framework was developed by Yeh, Hsu, Wu, et al. (2014) as the product of a two-stage study which started by generating the model and then validating it in a gradual study together with six researchers and 54 educators by using Delphi survey techniques. The experts were determined according to several principles and features. The six researchers were academics in instructional technology and 54 educators were faculty members with science teaching experience in high schools. Firstly, the researchers determined the possible competencies and knowledge types expected for teachers to be competent in using technology in teaching. Research panels were conducted with the researchers to build a temporary framework. Developed from technology, pedagogy, and content knowledge areas, the TPACK-P framework focused on five knowledge domains that are learners, subject and content, planning and design, practical teaching, and assessment (Yeh, Hsu, Wu, et al., 2014). Secondly, 54 educators provided opinions for the framework to reorganize and expand the model generated in the researchers' panel. Consensus was reached among the educators with some suggestions. Names of the knowledge dimensions were modified, more clarified descriptions were made, and some knowledge dimensions were combined. There are eight knowledge dimensions in the final model of the TPACK-P framework located under five pedagogical areas as illustrated in Figure 2.

It can be interpreted based on Figure 2 that the eight knowledge dimensions were constructed under five pedagogical areas which are learners, subject content, curriculum design, practical teaching, and assessment. The eight knowledge dimensions referring to these pedagogical areas are (i) using ICT to understand students, (ii) using ICT to understand content, (iii) planning ICT-infused curriculum, (iv) using ICT representations, (v) using ICT-integrated teaching strategies, (vi) applying ICT to instructional management, (vii) infusing ICT into teaching contexts, and (viii) using ICT to assess students. Learners, pedagogy, representations, and tool affordances are situated in the center of the framework (Yeh, Hsu, Wu, et al., 2014).

Content plays a significant role among the parts of the framework in directing teachers for determining student needs, comprehending the goals, designing instructional plans, selecting teaching strategies, technology choices, and assessment techniques for the goals (Yeh, Hsu, Wu, et al., 2014). Therefore, teachers are expected to develop domain-specific TPACK-P and be able to reconstruct their knowledge of TPACK-P for a specific content. In addition, the emphasis should also be given on context. Teachers are expected to design instruction by considering the affordances of and needs in the context (Yeh, Hsu, Wu, et al., 2014).

Figure 2.2 TPACK-Practical Framework. Reprinted from "Developing and Validating Technological Pedagogical Content Knowledge-Practical (TPACK-Practical) through the Delphi Survey Technique," by Y. F. Yeh, Y. S. Hsu, H. K. Wu, F. K. Hwang, and T. C. Lin, 2014, *British Journal of Educational Technology, 45*, p. 714.

In their proceeding research, Yeh, Lin, Hsu, et al. (2015) studied with practicing science teachers. Their aim was to identify and categorize teachers'

TPACK-P levels. The participating teachers were grouped according to their academic majors, experience in teaching, and award gains. The data were collected through semi-structured interviews and video-tapes of teachers' classroom instructions. Triangulation of the data revealed evidences for teachers' TPACK-P. Participants were evaluated according to five proficiency levels from 0 to 4 named as no idea, lack of use, simple adoption, infusive application, and reflective application, respectively. The levels proposed by Yeh, Lin, Hsu, et al. (2015) have a hierarchical structure. Level 0 indicates no use of and no information about technology. The other four levels indicate qualified behaviors and views in terms of TPACK-P. In addition, Yeh, Lin, Hsu, et al. (2015) determined the most common behaviors and views expected from teachers for each category. Then, they recorded these as the indicators for the dimensions. That is, the indicators showed the degree of competency for the dimensions in corresponding levels.

Yeh, Lin, Hsu, et al. (2015) categorized eight knowledge dimensions in TPACK-P into three domains of *assessment*, *planning and designing*, and *practical teaching*. *Assessment* domain covers gaining information about learners via ICTs. *Planning and designing* domain consists of strategies to design technology-infused lessons by considering learner needs and curriculum goals. *Practical teaching* domain is teachers' competency of implementing the technology-integrated instruction which meets learners' needs and suitable for the learning context (Yeh, Lin, Hsu, et al., 2015).

The analysis of the interview data revealed three types of teacher groups with different proficiency levels of TPACK-P as Technology Infusive (TI), Technology Transitional (TR), and Planning and Design (PD). Characteristics and practices of teachers in these three groups were thoroughly described in Yeh, Lin, Hsu, et al. (2015). A summary of these groups are provided here. Teachers in the TI group considered ICT use in a student-centered strategy. They were eager to design ICT-infused instructions, knew the affordances and constraints of ICT tools and selected appropriate tools for students' learning needs, allowed students to participate actively in learning with ICTs, and generate students' interpersonal interactions and their communication with the teacher through ICT support. Some of the teachers considered online communications such as blogs and forums as time consuming to organize and manage. Overall, teachers in this group were considered as high level teachers in terms of TPACK-P. Even some of them were found to be at Level 4 (reflective application and self evaluation). Secondly, teachers in the TR group showed teacher-centered approaches in their ICT-infused instructions. They were aware of ICT-infused assessments and considered them entertaining for students. However, they preferred usual assessment techniques which were traditionally common to them. Due to these teachers' subjectivity in approaching ICT use in planning and designing, their TPACK-P levels fit Level 2 (simple adoption). Lastly, PD group consisted of teachers who were competent in planning and designing ICT-infused instruction; however, they lacked interest in using ICTs in instruction and assessment. They were aware of the misconceptions and challenges that students faced and they suggested the use of ICTs to overcome these problems. On the other hand, they did not rationalize the assistance of technology in instructions and assessments. The knowledge of and practice in TPACK-P of teachers in PD group was not very similar to those in TI and TR groups. Compared to teachers in TR and PD groups, teachers in TI group elaborated on student-centered use of technology more and they were willing to adapt ICTs to assist their instruction.

Some of the builders of the TPACK-P framework and their colleagues (Jen et al., 2016) conducted a study to validate the TPACK-P framework proposed by Yeh, Hsu, Wu, et al. (2014) and to identify the edges of the proficiency levels for TPACK-P knowledge mentioned in Yeh, Lin, Hsu, et al. (2015) by using a standard-testing method. Jen et al. (2016) studied with a sample of 52 senior level pre-service and 47 in-service science teachers. More than 90% of the in-service teachers had at least five years of experience in the field. Moreover, all of the in-service teachers were experienced in technology use. They were either the attendants or the lecturers of workshops about teaching with technology and all of them expressed that they had experience in implementing technology-integrated instructions.

Jen et al. (2016) prepared a 17-item questionnaire which was consisted of

17 instructional scenarios and four response options for each scenario. In their first study about TPACK-P (Yeh, Hsu, Wu, et al., 2014), participating teachers mentioned their experiences that underlie the importance of technology integration to instruction. These experiences were considered while developing the scenarios. After building the scenarios, Jen et al. (2016) developed four responses for each item to meet the teachers' possible actions and views about scenarios. Teachers' interview data, which were collected previously in Yeh, Lin, Hsu, et al.(2015), were consulted to build options for the criteria and indicators of the TPACK-P levels. The four responses for each item were created such that each of them referred to the indicators depicted in each TPACK-P level.

After finalizing the 17-item questionnaire, the pre-service and in-service teachers were asked to select responses for the 17 scenarios in the questionnaire. The items were divided in two dimensions which were the knowledge of TPACK-P and the applications of TPACK-P. For the knowledge dimension, participants put the responses in the order of importance. For the application dimension, they selected one response that fit their classroom implementations. Participants' responses provided information about their knowledge and actions within various instructional contexts which were presented to them as instructional scenarios in the questionnaire. Analysis of the participants' responses to the 17-item questionnaire supported the proficiency levels in Yeh, Lin, Hsu, et al. (2015) study. Analysis showed that teachers sharing similar TPACK-P proficiency levels selected the same response options in the 17-item scale. Therefore, teachers with the same levels assumed to share similar views about technology use in instruction (Jen et al., 2016). The four proficiency levels of TPACK-P and benchmarks and indicators belonging to the levels introduced previously by Yeh, Lin, Hsu, et al. (2015) and then modified by Jen et al. (2016) were presented in Table 2.1.

Table 2.1

Benchmarks and Indicators of TPACK-P Levels

Levels	Assessment	Planning and designing	Enactment
Level 4 – Reflective application	Benchmark: Evaluate students’ learning of and about science before and after science learning.	Benchmark: Design technology-supported instruction that accommodates students’ learning of and about science.	Benchmark: Use technology skillfully to assist instructional material creation and student independent learning.
	Observed indicators: 1. Be able to use various representations or ICTs in instruction that enables teachers to identify students’ learning styles and learning difficulties (e.g., cognitive, affective) for the preparation of adaptive instruction. 2. Be able to construct technology-supported assessments through which students’ knowledge of and about science can be evaluated.	Observed indicators: 3. Be able to utilize functions of technology to facilitate teachers’ (their) and students’ exploration of scientific phenomena and construction of their science knowledge. 4. Consider and design technology-supported curricula for the purpose of enhancing students’ learning of and about science with skillful use of technology. 5. Be able to construct technology-supported curricula based on students’ prior knowledge or for purposes of inquiry learning, with strategic uses of digital representations or ICT tools. 6. Be able to use student-centered instructional strategies to accommodate students’ learning of and about science inquiry-based tasks in technology-supported environment.	Observed indicators: 7. Be able to use a variety of technology flexibly and strategically to accommodate students’ different learning needs, support their knowledge construction, and improve instructional effectiveness. 8. Be able to customize instructional materials with skillful uses of technology or multimedia resources for different instructional purposes.

Table 2.1

Benchmarks and Indicators of TPACK-P Levels (continued)

Levels	Assessment	Planning and designing	Enactment
Level 3 – Infusive application	Benchmark: Use technology to assess students before and after instruction.	Benchmark: Design technology-supported instruction from the student-centered perspective or with a focus on developing students' science learning.	Benchmark: Use technology flexibly to assist students' learning and teachers' instruction management.
	Observed indicator: 1. Be able to use appropriate technology or online platforms to observe students' learning styles and learning difficulties and to assist student learning. 2. Be able to implement appropriate multimedia or ICT tools into instruction for the purposes of evaluation and learning.	Observed indicator: 3. Be able to use appropriate representations or ICT tools to facilitate teachers' (their) and students' science learning through investigating and scientific phenomena and making virtual experiments. 4. Consider and design technology-supported instruction for enhancing instructional effectiveness and students' learning of science. 5. Be able to implement appropriate digital representations or ICT tools that facilitate students' learning of abstract concepts and scientific investigations. 6. Be able to use appropriate instructional strategies to facilitate teachers' instruction and student learning of science in technology-supported curricula (e.g. engaging students in collaborative learning).	Observed indicator: 7. Be able to use appropriate technology to improve the quality of content presentation, support communications, or build up students' learning profiles. 8. Be able to use different technology to manage instructional resources or track student learning progress.

Table 2.1

Benchmarks and Indicators of TPACK-P Levels (continued)

Levels	Assessment	Planning and designing	Enactment
Level 2 – Simple adoption	Benchmark: Evaluate students through presenting content with ICTs.	Benchmark: Design technology-supported instruction with a focus on developing students' content comprehension or learning motivation.	Benchmark: Use technology to make teaching more interesting and better supported.
	Observed indicator: 1. Be able to use different representations or ICTs to present science content, from which they observe students' learning performance and student learning is made possible. 2. Be able to use online assessments, digital representation or ICT tools to evaluate students' learning.	Observed indicator: 3. Be able to use representations or ICT tools for teachers (themselves) and students to learn abstract concepts. 4. Consider technology uses in instruction according to external factors or students' learning motivations. 5. Be able to present science content with digital representations that are available and good for enhancing students' learning motivations. 6. Be able to teach science with technology in couple of instructional strategies for the purpose of enhancing students' motivations and conceptual understanding.	Observed indicator: 7. Be able to implement technology in class to impress students in science learning and make teachers' instruction easier. 8. Be able to use word processors or online platforms to manage instructional resources.

Table 2.1

Benchmarks and Indicators of TPACK-P Levels (continued)

Levels	Assessment	Planning and designing	Enactment
Level 1 – Lack of use	Benchmark: Think technology make no specific contributions to student evaluation.	Benchmark: Think technology make no specific contributions to curriculum design over conventional teaching.	Benchmark: Think technology make no contributions to teaching practices.
	Observed indicator: 1. Think technology are not good tools to be used for knowing students' learning styles or learning difficulties. 2. Think technology-supported assessments are no different from conventional assessments or they have concerns regarding implementing ICTs to assist their assessments.	Observed indicator: 3. View learning science content through technology no better than learning from professional books or magazines. 4. Consider teaching with technology to be an alternative instructional method to conventional instruction. 5. Consider technology to be useful only in limited instructional occasions. 6. View teaching with technology to be good enough for instructional purposes, in need of no other teaching strategies for support.	Observed indicator: 7. Believe teaching with technology brings similar contributions to student learning as conventional instruction. 8. View current technology as not accommodating teachers' needs in instructional management.
Level 0 – No idea	Perform below level 1.	Perform below level 1.	Perform below level 1.

Note. Reprinted from "Science Teachers' TPACK-Practical: Standard-Setting Using an Evidence-Based Approach," by T. H. Jen, Y. F. Yeh, Y. S. Hsu, H. K. Wu, and K. M. Chen, 2016, *Computers & Education*, *95*, p. 49.

The indicators of the four TPACK-P levels were identified and validated for three domains of teaching which were assessment, planning and designing, and enactment as presented in Table 2.1. In addition to the indicators, the criteria for the teaching domains were explained under the title of benchmark. Teachers in levels 2, 3, and 4 showed similar features in terms of technology use in instruction. Moreover, for these levels, student-centered applications and effective use of ICT were more developed as the levels increased. On the other hand, teachers in levels 0 and 1 showed little or no willingness to know about or use technology in instruction (Jen et al., 2016).

Another result of the study by Jen et al. (2016) was that there was no significant difference between in-service and pre-service teachers' TPACK-P. In the study, although in-service teachers were expected to show higher TPACK-P level in terms of application, they did not develop better TPACK-P than PTs. Another prominent result was that although the knowledge levels of the participants were at levels 2 and 3, their applications stayed at level 1. In other words, participants demonstrated lower proficiency of TPACK-P in application compared to that of the knowledge about TPACK-P. Researchers suggested that these level differences in knowledge and application can be balanced by providing practice opportunities in teacher education programs (Jen et al., 2016).

Ay, Karadag, and Acat (2015) adapted the 17-item TPACK-P scale to Turkish context without any changes in the original scale. The scale with all its 17 items corresponded to eight knowledge dimensions under five pedagogical areas which were learners, subject content, curriculum design, practical teaching, and assessment as it was proposed by Yeh, Hsu, Wu, et al. (2014) in its original form. In their subsequent study, Ay et al. (2016) used the scale to investigate Turkish teachers’ technology integration in relation with four variables as gender, FATIH project implementation in school, school type, and experience in teaching. The data were collected from 296 teachers working at public schools. Within TPACK-P framework, it was possible to determine Turkish teachers’ knowledge and practice of TPACK in two pedagogical domains, which are curriculum design and assessment, and one knowledge dimension under practical teaching domain, which is using ICTs in instruction. About overall proficiency in TPACK-P, teachers had the highest averages in curriculum design domain and the lowest averages in assessment domain. In addition, teachers showed low proficiency skills in practical teaching domain. Ay et al. (2016) indicated that PTs' technological knowledge and integration skills need to be enhanced through teacher training especially within the context of Instructional Technologies and Material Design course, School Practice course, and Teaching Experience course.

TPACK is embedded in experience and develops through practice (Yeh, Lin, Hsu, et al., 2015). The aim of the current study was to develop PMTs' TPACK-P through their practices within a course about teaching mathematics with technology. In addition, the study aimed to determine PMTs' TPACK-P proficiency levels by investigating their technology-infused activity designs, lesson plans, teaching practices, and their knowledge about technology integration through the course. Therefore, the present study pursued the TPACK-P framework because the aim of the study was aligned with the rationale of the framework. The dimensions and indicators in the TPACK-P framework (Jen et al., 2016) were used to interpret the data collected throughout the study and to determine PMTs' TPACK-P proficiency levels accordingly.

CHAPTER 3

LITERATURE REVIEW

In TPACK literature, to identify what is missing carries crucial importance for knowing about pre-service teachers' (PTs) TPACK development in teacher education programs. This review aimed to address the related literature and identify the attempts for and gaps about developing TPACK in teacher education programs. In this respect, this chapter documented the TPACK models that focused on investigating different aspects of this complex knowledge and the intervention attempts to develop and measure TPACK in teacher education.

In the first part, the transformative and integrative views towards TPACK were explained briefly. Then, the models which were based on transformative view were described. In the second part, the role of teacher education in PTs' TPACK development was discussed. Then, the approaches for developing and investigating PTs' TPACK pertained to mathematics education within teacher education courses were presented in detail.

3.1 How to Give Meaning to TPACK: The Integrative View versus Transformative View

Canbazoglu-Bilici, Guzey, and Yamak (2016) stressed out the importance of deciding the view towards TPACK accurately in advance of conducting research on TPACK. In this section, the integrative and transformative approaches towards TPACK framework were briefly explained by mentioning the well-known researchers who advocate these perspectives. Then, the models generated from TPACK were summarized and synthesized with emphasis on the main principles they were grounded on.

According to the integrative view supporters, the seven knowledge types and their integrations form TPACK (Angeli, Valanides, & Christodoulou, 2016). Researchers, who were the integrative view supporters, intended to investigate the constructs of TPACK distinctively (Cox & Graham, 2009; Jaipal & Figg, 2015). For instance, emphasizing the technology related constructs of TPACK, Graham et al. (2012) investigated the TK related constructs of TPACK framework; TPK, TCK, and TPACK.

Some indicators correspond to more than one TPACK construct which leaves the decision to the researcher. This would lead to confusion between the studies which intend to investigate TPACK from an integrative view. Therefore, this view was transformed into how technology assisted instruction (Niess, 2005) imply the complex combination of knowledge constructs that emerge within teachers' knowledge and practices (Jen et al., 2016). Transformative view supporters expressed that rather than merely bringing TPACK components together, it is about forming a new type of knowledge by using the three constructs (i.e., PK, CK, and TK) and their integrations. Hence, TPACK is a unified and distinct body of knowledge that cannot be restricted to its sub knowledge domains (Angeli & Valanides, 2009, 2015; Thompson & Mishra, 2007; Yeh, Hsu, Wu, et al., 2014).

According to transformative approach supporters, TPACK knowledge includes the knowledge of context, student needs, pedagogy, tool affordances, and content (e.g., Angeli & Valanides, 2009). Angeli and Valanides (2009) indicated a counter argument towards integrative approaches towards TPACK by implying that integrative approach fails to explain technology integration in components of teaching and learning practices. In other words, components of technology integration in teaching and learning with pedagogy and transformation of these components with technology infusion are ignored in integrative approaches. Growth in PK, CK, and TK do not necessarily result in TPACK development (Angeli & Valanides, 2005). TPACK development can only be achieved if only it is regarded as an explicit unified body of knowledge that both pre-service and in-service teachers can present in their technology-infused designs and teaching practices (Angeli et al., 2016).

Almost all teacher education programs consist of instructional technology courses (Polly et al., 2010). These courses mostly depend on enhancing technological knowledge such as the affordances and constraints of technologies rather than presenting the interrelations with pedagogy and content (Bakir, 2016; Koehler & Mishra, 2009; Koehler et al., 2007; Mouza & Karchmer-Klein, 2013; Polly et al., 2010; So & Kim, 2009). However, TPACK can be developed through integration of technology considering pedagogical aims rather than only learning how to operate a technological tool (Yeh, Hsu, Wu, et al., 2014). Similarly, Papert (1997) criticized this view by referring it as technocentrism:

> When we talk about computers in education, we should not think about a machine having an effect. We should be talking about the opportunity offered us, by this computer presence, to rethink what learning is all about, to rethink education. (p. 4)

PTs need to develop their knowledge and skills about how to use technology for transforming content through various representations to enhance teaching and learning (So & Kim, 2009). TPACK is a framework that refers to and provides basis for this aim (Chai et al., 2013; Lee & Lee, 2014). Hence, studies shifted focus from technology-centered approaches to pedagogical approaches of technology (Ay et al., 2016; Koehler & Mishra, 2005). When designing and implementing technology-supported instructions, the focus should be on how technology is used rather than the type or frequency of its use (Yeh, Lin, Hsu, et al., 2015). TPACK framework asserts that the effective use of technology can be rated by its cohesiveness with the content (Graham et al., 2012), whether the technology-integrated instruction enhances learning, serves to meet student needs and learning styles, and appropriate instructional strategies are selected (Angeli & Valanides, 2009). Considering these aspects, researchers proposed and validated several models by raising the importance of specific knowledge and applications of TPACK.

3.1.1 Models of TPACK

TPACK is a fruitful framework that empowers potential for new approaches derived from it (Hewitt, 2008). Since it was first introduced, researchers proposed several models emerged from TPACK framework by addressing to different, intrinsic, complex, and contextual aspects and limitations of the framework to ascertain the variables that would have roles in TPACK (Angeli et al., 2016). Researchers proposed models that were adopted and derived from the epistemology of TPACK framework each of which grows upon a construct that the framework comprises. The unique parts of these models which approach TPACK from transformative view were provided in this part.

Koehler and Mishra (2005) and Koehler et al. (2007) proposed Learning Technology by Design approach in which they define PTs as practitioners. PTs engaged in lesson design activities in a collaborative environment. The approach supported transition from referring the constructs of TPACK separately to viewing it as an integrated knowledge. Koehler et al. (2007) investigated graduate students' discussions through a course when they were engaged in design activities. They concluded that students' TPACK was developed through the end of the course.

Angeli and Valanides (2005), as an initial attempt, proposed ICT-related PCK model as a unified body of knowledge including five knowledge types which were content, pedagogy, learner, ICT, and context. The ICT-related PCK model referred to the unique knowledge that appeared from the interaction of these knowledge types. Angeli and Valanides (2005) stated the following teacher competencies connected with effective teaching with technology:

> 1. Identify topics to be taught with ICT in ways that signify the added value of ICT tools, such as topics that students cannot easily comprehend, or teachers face difficulties in teaching them effectively in class.
> 2. Identify representations for transforming the content to be taught into forms that are comprehensible to learners and difficult to support by traditional means.
> 3. Identify teaching strategies, which are difficult or impossible to be implemented by traditional means, such as application of ideas into contexts not possible to be experienced in real life.
> 4. Select ICT tools with inherent features to afford content transformations and support teaching strategies.
> 5. Infuse ICT activities in the classroom. (p. 294)

Angeli and Valanides (2009) proposed ICT-TPCK Model by extending ICT-related PCK Model. They investigated primary PTs' TPACK development in their first two years in teacher education program through a three-cycled intervention. PTs' performances through technology mapping activities and peer-assessments about those activities were investigated. In technology mapping activities, participants identified the technology's role in accordance with its applicability to represent the content and coherence with pedagogical strategies. Next, PTs worked together on their instructional designs for peer-assessment. They were guided to assess the work according to the five criteria by Angeli and Valanides (2005) expressed above. Design activities supported PTs' TPACK development as also mentioned by Koehler et al. (2007). The peer-assessment practices provided PTs to develop ideas about efficient ways of incorporating technology to enhance their designs (Angeli & Valanides, 2009).

Technology-integrated approaches for teacher knowledge were suggested after technology showed presence in education. Based on Shulman's (1987) PCK framework, Grossman (1990, 1991) presented four components of teacher knowledge which were suggested as a base for developing teacher knowledge in teacher education programs. Niess (2005) added knowledge of technology to PCK as a main teacher knowledge specified for mathematics field and identified the following principles belonging to teacher knowledge relying primarily on the principles directed by Grossman (1990, 1991):

> 1) An overarching conception about the purposes for incorporating technology in teaching mathematics;
> 2) Knowledge of students' understandings, thinking, and learning of mathematics with technology;
> 3) Knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics; and
> 4) Knowledge of instructional strategies and representations for teaching and learning mathematics with technologies. (Niess et al., 2009, p. 8)

Niess et al. (2009) described a five-stage developmental model based on Rogers's (1995) model of innovation-decision process. This model helps to identify the progression of a teacher's effective integration of technology into mathematics learning environment. Mathematics Teacher TPACK Development Model suggests five levels; recognizing, accepting, adapting, exploring, and advancing (Niess et al., 2009):

> 1. Recognizing (knowledge), where teachers are able to use the technology and recognize the alignment of the technology with mathematics content yet do not integrate the technology in teaching and learning of mathematics.
> 2. Accepting (persuasion), where teachers form a favorable or unfavorable attitude toward teaching and learning mathematics with an appropriate technology.
> 3. Adapting (decision), where teachers engage in activities that lead to a choice to adopt or reject teaching and learning mathematics with an appropriate technology.
> 4. Exploring (implementation), where teachers actively integrate teaching and learning of mathematics with an appropriate technology.
> 5. Advancing (confirmation), where teachers evaluate the results of the decision to integrate teaching and learning mathematics with an appropriate technology. (p. 9)

According to Niess et al. (2009), teachers progress through these five stages in order from recognizing to advancing when learning how to integrate technology in teaching mathematics. This model has been frequently used among researchers to define TPACK levels of teachers. However, the levels show complexity when deciding the boundaries between them. Hence, other models were proposed based on Mathematics Teacher TPACK Development Model without hierarchical levels to remedy these issues or focused on other aspects.

Koh and Divaharan (2011) proposed TPACK-Developing Instructional Model to support PTs' TPACK development. They criticized that the previously proposed models (e.g., Angeli & Valanides, 2009; Koehler & Mishra, 2005) depended on how design activities facilitated TPACK development. Therefore, they developed a model for TPACK development through experiencing unfamiliar technological tools within three instructional phases. These phases were proposed based on the five stages described by Niess et al. (2009) in Mathematics Teacher TPACK Development Model. The first phase, *Foster Acceptance Phase*, recommended the use of technological tools to facilitate teachers' own instruction. The second phase, *Technological Proficiency and Pedagogical Modeling Phase*, emphasized the awareness of how teaching strategies can be supported with the affordances of technology. Subject-specific technology integration was about exploring technology affordances and using effectively to represent the content. The third phase, *Pedagogical Application Phase*, included designing technology-integrated activities and lesson plans to explore and develop skills about how technology can foster teaching and learning. Although the phases referred to the sub-constructs of TPACK framework, the model overall aimed at developing TPACK as a unique knowledge and reforming teacher education programs.

TPACK is embedded in experience and develops through practice (Yeh, Lin, Hsu, et al., 2015). Yeh, Hsu, Wu, et al. (2014) proposed TPACK-P framework as knowledge-based and experience-driven set of teacher competencies. Eight knowledge dimensions were constructed under five pedagogical areas at the end of the consensus from a group of researchers and educators. This model was proposed as a path way for teachers who intend to design and implement technology infused courses. Yeh, Lin, Hsu, et al. (2015) identified observable indicators and exemplary behaviors of teachers to determine teachers' proficiency levels in terms of technology integration in practice. On the basis of practical use of technology in education, TPACK-P framework proposed four proficiency levels in *Assessment domain*, *Planning and Design domain*, and *Enactment domain* (Jen et al., 2016). Deriving from both knowledge- and practice-based nature of TPACK and emphasizing content-specific development, TPACK-P framework is distinctive from the other models of TPACK.

3.1.2 Measurement of PTs' TPACK

PTs' knowledge of and skills about technology integration need to be analyzed from the pedagogical perspective and specific to the subject matter (Chai, Koh, Tsai, & Tan, 2011). Different methods and valid, reliable, and robust instruments for measuring TPACK development were needed (Mishra & Koehler, 2006; Schmidt et al., 2009). Thus, a variety of qualitative and quantitative instruments were developed for understanding the nature of TPACK (Schmidt et al., 2009). Among these techniques (i.e., surveys, performance assessments, interviews, observations, and open-ended questionnaires) and related instruments (Koehler, Shin, & Mishra, 2012), the prevalently valid and reliable thereby preferred and applied techniques and instruments in the related literature were presented in this part.

Schmidt et al. (2009) constructed the Survey of Pre-service Teachers' Knowledge of Teaching and Technology. The survey included demographic questions and served for measuring all seven subscales of TPACK. The survey addressed the mathematics, science, social studies, and literacy content areas. It was a commonly used survey in the literature both for investigation of PTs' perceptions of their TPACK development through time and for generation of other reliable TPACK surveys (Niess, 2011). Further instrument validation studies of Schmidt et al.'s survey were also conducted (e.g., Chai, Koh, Tsai, & Tan, 2011; Koh, Chai, & Tsai, 2010).

TPACK-deep scale, developed by Kabakci-Yurdakul et al. (2012), was another attempt to assess PTs' TPACK. The scale was comprised of 33 items under four factors of design, exertion, ethics, and proficiency. Design factor is aligned with competencies of designing technology-enhanced instruction and materials; exertion factor is the competency of implementation of the design; ethics factor is about the ethical awareness; and proficiency factor comprises innovativeness, problem solving, and field specialization. TPACK was the center of these four factors and was embedded in the items of the scale which reflects the transformative approach towards measuring TPACK (Kabakci-Yurdakul et al., 2012).

Tondeur, van Braak, Siddiq, and Scherer (2016) developed a self-report instrument to measure PTs' perceived support from their teacher training institutions about developing skills for integrating technology into practice. In this respect, the instrument was suggested to be used to identify the effective strategies needed to develop PTs' technology integration skills. The instrument was based on six of the twelve themes determined by Tondeur et al. (2012) in Synthesize Qualitative Data (SQD) model as effective strategies in teacher preparation programs to improve PTs' technology integration skills. The selected strategies for developing the items of the self-report instrument were researchers being the role models, reflecting on successful implementations, collaboration, authentic experience, and feedback.

TPACK is considered as a situated, complex, and multidimensional knowledge that requires deep investigation. Therefore, in addition to exploring PTs' TPACK via surveys, qualitative approaches were also used. PTs' TPACK was investigated through evaluating lesson plans and implementation of the designs. Performance assessments have been utilized for teaching experiences such as micro-teaching. For instance, Harris, Grandgenett, and Hofer (2010) constructed Technology Integration Assessment Rubric to assess TPACK through the investigation of lesson plans. The rubric served for scoring lesson plans ranging from one to four in four dimensions regarding (1) alignment of curriculum goal with technology, (2) alignment of technology with instructional strategy, (3) compatibility of the technology with the content and instructional strategy, and (4) overall harmony between three constructs. Yeh, Chien, Wu, and Hsu (2015) recommended utilization of rubrics for evaluation of lesson plans and implementation of the plans via micro-teaching. Hence, Yeh, Chien, Wu, et al. (2015) developed a rubric that would be helpful in both preparation and evaluation of PTs' technology-enhanced implementation performances. While interviews, mostly semi-structured, and open-ended questionnaires provided researchers about overall experience with technology, observations reveal the TPACK in practice (Koehler et al., 2012).

As a result of a systematic investigation of both theoretical and practical TPACK studies, Voogt, Fisser, Roblin, Tondeur, and van Braak (2012) recommended that demonstration of content-specific technology-integrated applications, assessment instruments of these designs, and applications need to be investigated. TPACK studies investigating technology use in practice (Voogt et al., 2016) within content-specific domains (Voogt et al., 2013) are needed. Niess (2011) suggested that future studies should provide examples of teacher education applications such as courses, programs, or instructional manipulations that ensure development and assessment of PTs' TPACK.

3.2 PTs' TPACK Development: The Role of Teacher Education Programs

Teacher education programs have a crucial role in PTs' TPACK development and attitudes and self-efficacy towards technology integration

(Tondeur, Scherer, et al., 2017). Engaging in design activities about technology integration, collaboration with peers, and providing feedback have been some of the suggested strategies in teacher education programs to develop PTs' competencies about effective technology integration in classroom practice (Tondeur, van Braak, et al., 2012).

Teacher education programs have great influence on newly graduated teachers' technology integration in their instructions (Tondeur, Roblin, et al., 2017). However, it has been a challenging and debated issue to fulfill this aim in teacher education programs (Niess, 2011) since PTs' technology integration skills are not well-developed through their teacher education (Aslan & Zhu, 2016; Tondeur, van Braak, et al., 2012). Profiles of both PTs and starting teachers having less than three years in teaching profession revealed that basic level use of technologies were not effective for discovery or experiment (Aslan & Zhu, 2016). Tondeur, Roblin, et al. (2017), drawing upon from beginning in-service teachers' experiences, indicated that teachers need to experience designing technology-integrated concrete activities through their teacher education. Aslan and Zhu (2017) investigated PTs' practices to find out ICT-related variables predicting their ICT-integration. They reached 599 fourth-year PTs from four different subject areas that were Turkish language education, science education, elementary mathematics education, and social sciences education. Among the variables, pedagogical knowledge, ICT-related courses, and PTs' perceived competency in ICT use were found to predict 17 % of PTs' ICT integration into practice.

Tondeur, Scherer, et al. (2017) identified PTs' ICT profiles related with their ICT related characteristics and perceived technological support they gain from teacher training institutions. In the study, researchers developed a survey for identifying PTs' characteristics which were related with support provided by the teacher education institutes about technology integration in relation with the factors defined in the synthesis of qualitative evidence model and their TPACK. The survey was comprised of three sub-scales measuring PTs' (1) technology dimensions of TPACK, (2) attitudes towards ICT use, and (3) perceived technology support by the teacher training institutes according to synthesis of qualitative evidence model. As a result, two PT profiles were emerged as low and high educational ICT profiles. The important result of the study was that support provided by teacher training institutes was correlated with the direction of the PT profile.

Tondeur, van Braak, et al. (2012) reviewed 19 qualitative articles to reveal effective strategies in teacher education programs to develop PTs' technology integration to classroom practices. In the light of the analysis, researchers identified the effective strategies in terms of key themes related with PTs' preparation and institutional conditions. Linking theory with practice, learning technology integration by designing, the teacher educator being the role model, and working collaboratively with peers were among the 12 key themes identified for PTs' preparation for technology-integration in their teaching practices.

Polly et al. (2010) analyzed the findings of the peer-reviewed journal articles and project evaluation reports related with The United States Department of Education's Preparing Tomorrows Teachers to Teach with Technology (PT3) initiative projects. These projects aimed at transforming teacher training programs focusing on changes in some courses and field practices. Researchers indicated that there had been several approaches to develop PTs' technological integration skills. These approaches were infusing technology to faculties, enhancing instructors' technology integration skills, providing assistance for the technology-integrated activities in methods courses through mentoring, and developing technology-enhanced instructional materials. Besides, PT3 projects brought some changes to teacher education programs. Infusing technology to methods courses and field practices supported the development of PTs in terms of technology integration.

PTs need to experience technological knowledge in relation with integration to educational content (Tondeur, van Braak, et al., 2012). Teacher education programs recently aim at motivating PTs "to think critically about using technology" (Bakir, 2016, p.27) for making sensible choices to integrate into their teaching practices. Yeh, Hsu, Wu, et al. (2014) indicated the role of teacher education programs in TPACK development by linking it to the principles of TPACK framework:

> From the transformative point of view, teacher education programs should focus on preparing teachers to customize subject-specific curricula with a consideration for both learners and contexts, through a recursive process of instructional planning, enacting and reflecting. Knowledge transformation is indispensible when technology is included in PCK. Inherited from PCK, TPACK is also a unique body of knowledge into which constituent bodies of knowledge not only should be integrated but inside of which those constituent bodies must be transformed. (p. 710)

It has been a common and effective approach to develop and examine PTs' TPACK through technology-integrated lesson designs (Chai et al., 2013) and implementation (Niess, 2011; Yigit, 2014). Technological knowledge needs to be blended within pedagogical knowledge related with content should take place within methods and field experience courses rather than merely informing about the uses of technological tools (Mishra et al., 2009; Niess, 2012). Lesson planning, micro-teaching, and field experiences are activities in an increasing order of influence on PTs to align theory with practice (Lee & Lee, 2014).

There is a need for further studies presenting development of technology-enhanced settings that are based on TPACK framework principles (Chai et al., 2013). When integrating technology to education, teachers are in the position of a decision-maker selecting the ICT that best meets the related educational objective in the particular content of a specific field of study. Literature provides evidence for developing PTs' TPACK in various course settings and methods. These studies were extensively covered in the following section.

3.2.1 Approaches for Development of PTs' TPACK in Mathematics Education

Exemplary attempts for TPACK development such as instructional interventions mainly in mathematics education were presented in this section. The related literature embraces a variety of studies about development of PTs' TPACK through courses. A systematic search of different combinations of keywords which were "pre-service mathematics teachers TPACK" and "TPACK course" on online databases were conducted. There were no time limit set in the search and the research studies approached were published between 2005 and 2018. In addition, the related studies indicated in the review articles and the handbooks of AACTE (2008), Angeli and Valanides (2015), and Herring, Koehler, and Mishra (2016) were examined. Among all, the studies aimed at developing and investigating PTs' TPACK in mathematics field that were employed in teacher education courses, excluding the online courses, were selected. In this part, these studies were addressed by mainly focusing on the strategies that were used to develop TPACK, the technologies selected, the assessment techniques to measure TPACK, and the main results.

Huang and Zbiek (2016) reviewed 18 articles which were selected from six refereed core mathematics education journals. These articles were about pre-service secondary mathematics teachers' experiences of using technology in three contexts: Mathematics content courses, methods or pedagogy courses, and teaching practices. In this critical review, it was concluded that engagement with technological tools enhanced pre-service mathematics teachers' subject matter knowledge and attitudes. Integration of mathematics-related technologies and video-based cases supported PTs to design technology-infused courses and consider and identify students' learning needs and styles. However, support for the development of integrating technology to teaching practice was still needed.

Chai et al. (2013) searched four broad databases and selected 74 journal papers about technology integration based on TPACK framework dated back from 2003 to 2011. Among the 55 empirical studies, 17 intervention studies examined course designs to improve PTs' TPACK. The intervention studies were concerned with empowering the effectiveness of the teacher education courses for TPACK development. There were 10 studies in the mathematics field. The mathematics-specific technologies employed in these studies were Geometer's Sketchpad, GeoGebra, Cabri Geometry, graphing calculators, and simulation applets. The subject-general technologies utilized in these studies included Tablet PC, PowerPoint, spreadsheet, virtual manipulatives, and interactive white boards.

Yigit (2014) conducted a systematic literature review study consisting 17 peer-reviewed articles about pre-service mathematics teachers' development and assessment of TPACK in terms of the strategies and assessment techniques published between 2005 and early 2013. There were 15 empirical articles among these and 11 of them were different than the studies reviewed in Chai et al. (2013).

In the light of the extensive review, Yigit (2014) concluded that TPACK framework could provide basis for teacher education courses to develop pre-service mathematics teachers' competencies to design and implement technology-integrated mathematics activities and instructions, and to enhance and assess their TPACK.

Baran and Canbazoglu-Bilici (2015) reported a critical analysis of the TPACK studies conducted in Turkey. The systematic analysis revealed 30 research articles published between 2015 and 2013 which utilized TPACK framework in teacher education contexts. In Turkey, TPACK studies had mostly been conducted with the use of surveys. Moreover, among the investigated studies, design and application studies were conducted through redesigning existing or designing new teacher education courses based on TPACK framework principles. The most frequent courses redesigned were the second Methods courses and Instructional Technologies and Material Design courses. There were five studies among 30 which focused on pre-service elementary and secondary mathematics teachers' TPACK development. There were a few studies conducted with content-specific technologies. Moreover, in qualitative studies, context was not described in detail (Baran & Canbazoglu-Bilici, 2015) which limits the further studies to make comparisons and develop better contexts.

Niess (2005) conducted a study to develop PTs' TPACK throughout a year in teacher education. PTs majoring in fields of science and mathematics enrolled to courses about pedagogy, technology, and micro-teaching implementation. In the first semester of the study, PTs engaged with technologies within several activities, discussed pedagogical approaches, and enacted courses through micro-teaching. In the second half, they involved in practical uses of technology within course designs and implementations of those plans. They planned, taught, and reflected on each other's performances. PTs revised their lesson plans in accordance with the feedback from the instructor, the cooperating teacher, and peers. The results indicated that 14 PTs showed considerable increase in TPACK in terms of integrating technology to enhance students' science and mathematics learning.

In some studies, researchers have focused on the use of specific technologies to improve PTs' TPACK. For instance, Balgalmis (2013) focused on the use of GeoGebra technology to develop pre-service middle school mathematics teachers' (PMTs) TPACK within the field experience course. PMTs designed lesson plans and enacted three mathematics courses at a middle school. These lectures were developed with reflection-on-action method which was found to be effective in increasing TPACK levels. PMTs' TPACK levels were identified based on Niess's (2005) TPACK Development model through the rubric generated by Lyublinska and Tournaki (2011). The results of the study showed that at the end of the three authentic implications of technology-assisted mathematics courses, PMTs expressed the influence of technology utilization in enhancing students' learning and motivation.

Cavin (2008) conducted a practice-based study that PTs developed TPACK through micro-teaching experiences. The researcher designed a course lasted for one semester and conducted three hours a week. Five PTs were majoring in mathematics education and one PT was enrolled in science education department. PTs engaged in a cycled-practice in which they worked in groups and taught, reflected, and modified technology-integrated mathematics courses repetitively. The data were collected through video and audio records, documents, observations, and interviews. TPACK framework and curriculum standards in conjunction with the framework were used to analyze the data. The course technologies contained several types of graphing calculators and the spreadsheet software Excel. It was indicated that before micro-teaching experience, PTs considered technology useful for computational utility which saves time. After engaging the repetitive cycle, they considered technology useful for providing conceptual understanding. PTs indicated that collaborative work with peers facilitated their technology-integrated lesson designs. In addition, it was asserted that PTs recognized the need for pedagogical shift when technology was integrated to course in a student-centered learning environment.

Agyei and Voogt (2012) investigated the influence of working in collaborative design teams on four PMTs' integration of technology-enhanced lessons and on their TPACK. The research aimed at identifying PMTs' views on the influence of working in design teams to examine exemplary curriculum materials, design technology integrated materials and lesson plans, PMTs' classroom implementations and the peers' views on these micro-teachings, and PMTs' TPACK development. PMTs engaged in two design teams in a collaborative environment where they developed curriculum materials to provide solutions to the authentic problems they faced in teaching practice experiences in school training. The researchers aimed at promoting the view of technology as an educational tool to reach educational goals and learning by active engagement in the collaborative environment in design teams. Moreover, the researchers relied on goals and materials in the curriculum to direct PMTs develop more qualified technology-enhanced student-centered materials. PMTs were guided to design and implement spreadsheet-supported mathematics materials. Spreadsheet was selected as the technology to enhance mathematical thinking skills and for being user-friendly and available in high schools and teacher education classrooms. The professional development process consisted three parts which were (i) a two-week workshop about theoretical base of TPACK and two practical examples of spreadsheet applications, (ii) three-week collaborative lesson design, and (iii) implementation via 80-minute micro-teaching for each PMT. Data sources were interviews about the design and implementation process, a self-evaluation questionnaire adapted from Schmidt et al. (2009), group discussions, a 23-item questionnaire to obtain 125 peers' views about micro-teachings, and researcher's field notes. The PMTs expressed that they gained confidence about using spreadsheet to teach mathematics as they worked more on lesson and material designs. They expressed that their implementations were student-centered and encouraged participation. The spreadsheet was used in the implementations for verification of calculations, demonstrating the relationship between functions and graphs, exploring multiple graphs in less time, and exploration of number patterns. The researchers concluded that TPACK development was evident in four PMTs' implementations and self-reports and that collaborative design supported this development. The researchers criticized the use of one technology type for the possibility of resulting in design challenges and overuse of the tool. Time management in the implementations was not easy for PMTs for the reason that the plans were overloaded. Researchers indicated that PMTs were in need of more practice for enhancing their TPACK competencies. This was an example of a short-term study in which the effect of the implementation and design team work on PMTs' TPACK was examined through design and implementation by using a single technology.

PTs gain the role and responsibility of a mathematics teacher when they are provided with the proper environment to integrate knowledge constructs of TPACK (Ozgun-Koca et al., 2010). Ozgun-Koca et al. (2010) investigated pre-service secondary mathematics teachers' TPACK development through TI-Nspire graphing calculator supported designs and implementations in their first methods course. Within the context of the course carried out by inquiry-based learning, 22 PTs engaged in content-specific and pedagogical activities. PTs designed lesson plans and activities supported with TI-Nspire which they implemented afterwards as part of their field experiences. It was revealed that PTs' views on the role of technology in mathematics education shifted from technology as a reinforcing tool to technology as a tool supporting development of mathematical understanding. Another result was that, changes observed in PTs' identities through the methods course as being teachers of mathematics rather than learners of mathematics (Ozgun-Koca et al., 2010). Regardless of their improved confidence towards integrating technology in their future teaching, PTs were reluctant to utilize technology in their implementations when it was not compulsory. It was suggested that more emphasis on practical application of technology in authentic settings was needed.

In their following study, Meagher et al. (2011) examined PTs' use of TI-Nspire graphing calculator technology in terms of the roles of technology and inquiry strategy in their lesson plans and the implementation of the technology-integrated mathematics courses. PTs' technology usage was investigated in their lesson plans and in the two implementations of the lesson plans through a two-week teaching practice in both middle and high schools. The tasks and assignments consisted of field experience reports, five secondary level mathematics activities, and a project in which they searched problems and suggested ways to be solved with the support of TI-Nspire graphing calculator. PTs filled in four surveys with multiple-choice and open-ended questions in three different weeks of the course and another survey at the end of the course. The surveys mainly investigated PTs' views about teaching, experiences with technology in the course, experiences in relation with technology and mathematics in class, and experiences in the field practices. These altogether served for identifying their views regarding their development of TPACK throughout the semester. The analysis was based on the components defined by Niess (2005). The results showed that PTs viewed graphing calculators as supportive tools for doing mathematics, useful in terms of discovering algebraic rules and providing facilities to explore a problem in multiple ways. PTs' ideas reflected higher level of TPACK than it was in their lesson plans. Most of the PTs agreed that they learned practical uses of technology in teaching and learning of mathematics throughout the methods course. Although most of the PTs expressed that field experiences enhanced their critical thinking towards technology enhanced mathematics teaching, the inconsistent views emerged from lack of technological equipments in the practice school or participants' lack of interest or ability of technology to integrate in teaching mathematics. Almost half of the PTs did not consider field experience as a support for designing technology-integrated activities or lesson plans. The researchers recommended that PTs need more than a methods course and authentic practices to enhance positive attitude towards technology integration in education.

In these two studies, the one-semester methods course depended mainly on a single technology, the TI-Nspire graphing calculator. Moreover, it was an early attempt for field practice since PTs engaged the course in their early years at the teacher education program. Therefore, the course content also consisted of pedagogical and content related information for PTs. The content of the three knowledge types (i.e., TK, PK, and CK) were new for them. In addition to these, designing lesson plans and field practice were among the assignments of the course. Gaining knowledge, designing, and classroom implementation altogether can be considered as an over-loaded program for PTs.

Meng and Sam (2013) conducted a study of six-week program with a single group consisting 46 pre-service secondary mathematics teachers as a part of a methods course which aimed at TPACK development. The lesson study part of the course was designed as a professional development program for PTs in developing skills for Geometer's Sketchpad integration to secondary mathematics education. The researchers expressed that Geometer's Sketchpad was chosen for being useful in several mathematics subjects related with Algebra, Statistics, Trigonometry, and Geometry which provide dynamic manipulation and promote mathematical inquiry. The lesson study was a special type of professional development which started with two one-hour workshops provided by the researchers to the PTs in four groups. The workshops covered the instructions for Geometer's Sketchpad use and the design of activities about secondary mathematics content. Then, it continued with collaborative planning of a lesson, activity sheets, and related Geometer's Sketchpad sketches in groups of two, individual implementations to peers, discussion on these implementations, revision of the plans, implementation of the revised version, and discussion about the final implementations. The Survey of Pre-service Secondary Teachers' TPACK for Teaching Mathematics scale by Schmidt et al. (2009) was conducted as pre and post tests. The survey was adapted to be aligned with the research aim and design. The technology word was changed to Geometer's Sketchpad and the content knowledge subscales (i.e. mathematics, literacy, science, and social sciences) were changed to Algebra, Statistics, Trigonometry, and Geometry. The results confirmed a significant development in PTs' TPACK about teaching mathematics with Geometer's Sketchpad. This was another example of a single-technology short-term study requiring practical applications to develop TPACK.

Bowers and Stephens (2011) designed and implemented a 6-week course which took place in a computer laboratory with 21 PTs, 16 of which were pre-service secondary mathematics teachers. Participants were free to attend face-to-face, online, or both sessions of the course for 3 hours a week. They were required to write views on the web-based discussion board and hand in TPACK project assignments. The project assignments required PTs to choose a mathematics topic and produce an activity on Geometer's Sketchpad to support textbook content. In addition to the activity plan, PTs were asked to express the topic and the expected result of the activity; identify the goal for utilizing several features of Geometer's Sketchpad such as providing exploration and visualization and remedying misconceptions; and explain the support of the activity plan to the textbook context. PTs presented their activities to their peers and discussions were held as a class. In the analysis, attempts for building mathematical relations and probing questions that encourage learners to think from different perspectives were considered in PTs' plans and presentations when determining TPACK development. The results indicated that only three of the plans demonstrated TPACK. This was explained by the mode of attendance to the course that the online attendees showed the minimum development of TPACK. Reflecting on each others' work and classroom discussion both online and face to face were expressed as the powerful strategies for developing PTs' TPACK in mathematics. The course model might be considered insufficient in terms of time and technology type since Bowers and Stephens (2011) also recommended repeating the study with other technologies.

Lee and Hollebrands (2008) conducted a study as a part of the project called Preparing to Teach Mathematics with Technology. The instructional model involved probability and statistics in a methods course based on the principles of TPACK asserted by Koehler and Mishra (2005) and Niess (2005), and recommendations in AMTE (2006). The aim of the study was to develop PTs' TPACK integrally through participating in technology-enhanced tasks, reflecting on the tasks from students' point of view, watching a video about the authentic implications of the same tasks, and criticizing the students' performances on the sample course video. It was indicated that reflecting on their work was useful for PTs' future professions as teachers and working in groups was a useful strategy for developing and identifying PTs' reasoning of TPACK. It was reported that, although PTs' technology utilization skills were developed, they lacked pedagogical understanding.

Mudzimiri (2012) aimed at developing five PTs' TPACK in three associated and concurrent courses within the same semester. These courses were methods for teaching mathematics, technology-supported mathematical modeling, and teaching practice. TPACK survey, teaching philosophy statements, technology-integrated lesson plans and implementation of these plans, and researchers' field notes were the data sources to investigate PTs' TPACK development. The survey was a combination of open-ended questions based on the four components expressed by Niess (2005) and mathematics content related items of the TPACK survey developed by Schmidt et al. (2009). The lesson plans and implementations were analyzed based on the rubric developed by Lyublinskaya and Tournaki (2011). The researchers concluded that PTs' TPACK was affected by many variables such as prior knowledge about and experiences with technology, mathematics content knowledge, and beliefs about using technology in teaching mathematics.

Akkaya (2016) employed a mixed methods research with 34 PMTs to develop and identify the changes of perceptions regarding technology integration in teaching mathematics. The researcher provided PMTs with training on TPACK in the context of a course which was three hours a week and lasted for a semester. GeoGebra, Cabri, and TI-Nspire graphing calculator were the technologies utilized in the context of the course. The course covered theoretical knowledge about TPACK, application of mathematical activities with the three technologies, micro-teaching practice in groups, and feedback from peers and the instructor. Perception Scale for Technology Use (Oksuz, Ak, & Uca, 2009) was employed as pretest and posttest. PTs' written views were obtained through five open-ended questions about technology use in teaching mathematics after the training session. In addition, PMTs' lesson plans, micro teaching videos, and interviews were the other data sources. Overall data analysis showed that the training which integrated pedagogy, content, and technology enhanced PTs' perceptions towards technology use in mathematics education. There were applications which provided environment for students to construct their own knowledge. As it was indicated in the study, all PMTs selected geometry subjects in their micro-teachings. PMTs mostly preferred dynamic geometry software, whereas, they did not prefer to utilize virtual manipulatives in the micro-teachings. The results revealed that PMTs' perceptions towards incorporating technology in mathematics teaching improved in the course. Similar to Akkaya (2016), Durdu and Dag (2017) conducted a mixed-methods study with same data collection sources with 71 PTs in their fourth year in several departments of the teacher education program. Researchers designed and implemented the Computer-based Mathematics Course. The influence of the course on TPACK development and on its knowledge constructs, the relationship between micro-teaching experience and TPACK development, and the change in conceptions towards integrating technology in teaching and learning of mathematics were examined in the study. Besides the results about the knowledge constructs of TPACK, the course contributed to PTs' TPACK development. In addition, a significant relationship was reported between micro-teaching scores and TPACK scores.

According to Akkaya (2016), emphasis should be on developing teachers' perceptions in order to enhance their technology use. The broad course content, mixed method approach with the multiple data sources, and the length of the study were effective for TPACK development and assessment. Although the findings did not rely only on self-reported data, the course context was limited to three content-oriented technologies, which in turn would have limited PMTs' mathematics goal selections in lesson plans. Similarly, in the study conducted by Durdu and Dag (2017), the course content and assignments were based on one type of technology, GeoGebra software, which would have limited PTs' selections of the mathematics subjects. In the study conducted by Akkaya (2016), PMTs were in their third year in the teacher education program. Although it was expressed that PMTs were informed with related knowledge about teaching methods, they did not complete the methodological and pedagogical courses and did not experience teaching practice yet. This might have affected their TPACK development, and especially their practices. Although Durdu and Dag (2017) held an integrative view towards TPACK framework in the analysis, the courses in both studies were attentive examples of teacher education courses aiming at developing PTs' TPACK.

Akyuz (2016) examined PTs' TPACK development in the context of

Exploring Geometry with Dynamic Geometry Applications course which was designed and implemented by the researcher. The participants were 58 junior, 18 senior, and 4 graduate students in different fields enrolled to the course in five different semesters. The course was implemented with different instructional strategies that were design-based strategy, problem solving-based strategy, and activity-based strategy. Dynamic geometry activity, worksheet, and lesson plan referring to a learning goal in the curriculum were used as the data sources. Four from each assignment were gathered from 80 participants. The micro-teaching of the selected course assignments were also used as the data source. The theoretical model proposed by Bowers and Stephens (2011) was adapted for the data analysis. As a result, 28 participants were detected having high level TPACK at the end of the course. Other participants mostly lacked pedagogical knowledge. Design-based strategy outperformed activity-based strategy. In addition, problem solving-based strategy was detected to have the least influence on TPACK development among other strategies. The results also revealed that there was a positive correlation between the grade level and TPACK development. The study was broad in terms of mathematics content but was restricted to the GeoGebra and Cabri 3D dynamic geometry tools as the aim of the research and the content of the course were aligned with this selection.

Kurt (2016) aimed at developing and assessing PMTs' TPACK in a course about statistics. After being informed about the types of virtual manipulatives that could be incorporated in teaching statistics, 9 PMTs were assigned to design lesson plans collaboratively in two groups by using virtual manipulatives. Then, they performed micro-teachings of these lesson plans. Pre-interviews were conducted to identify PMTs' views towards teaching statistics and integrating technology to teaching this subject. In addition, Distinguishing Teacher Assessment in Statistics Test was conducted to identify PMTs' pedagogical and content knowledge. PMTs' TPACK development was observed via micro-teaching lesson study. The micro-teaching lesson study was found to be effective on PMTs' TPACK development. This study was limited to statistics subject and one type of technology which was virtual manipulatives since the aim of the research was aligned with these preferences.

Mouza and Karchmer-Klein (2013) investigated PTs' TPACK development through the five-week period of the Integrating Technology in Education course. Participants were the junior and senior students in three different fields which were literacy and social studies, science, and mathematics. They enrolled to the methods and field placement courses at the same semester with the course. The PTs' beginning TPACK was identified through the Survey of Pre-Service Teachers' Knowledge of Teaching and Technology developed by Schmidt et al. (2009). The results showed that PTs experienced primitive technology utilization such as projectors by their instructors at K-8 or university education. They did not experience any technology support for enhancing learning and had no idea about integrating technology, pedagogy, and content. In the course, PTs were firstly introduced with certain technologies such as concept mapping programs, interactive manipulatives, Internet resources, and Web 2.0 tools. TPACK framework was explained to support their technology-integrated lesson designs. Course projects and assignments required technology-supported designs by utilizing different tools. The course projects required a critique on an exemplary technology-integrated course, proposing lesson designs about utilizing concept mapping software, enacting the lesson plans, and reflecting on their implementations. Among the 58 PTs enrolled to the course, 22 PTs' lesson plans were analyzed according to the Technology Integration Assessment Rubric constructed by Harris, Grandgenett, and Hofer (2010) and evaluated in terms of eight pedagogical decisions proposed by Harris and Hofer (2009). In addition to lesson plans, case reposts were analyzed to reveal what PTs learned from their experiences. Although the analysis corresponded some of the TPACK constructs separately, results for PTs' overall TPACK indicated development that PTs raised awareness about the interactions among technology, pedagogy, and content. There were inconsistency between lesson plans and instructions in the field placements. This research was exemplary for utilizing case development pedagogy for including extensive analysis of case reports provided by PTs' designs and implementations. However, PTs were not introduced with the content-specific technologies. Although PTs conducted instructions in authentic setting, the elementary and middle schools were not equipped with the technological resources. This caused implementation problems as indicated by Mouza and Karchmer-Klein (2013). Moreover, the five-week period was considerably insufficient. The design, enactment, and reflection cycle implemented in this study would be effective to be the end of a technology integration course. In their following studies (i.e., Mouza, et al., 2014; Mouza, Nandakumar, Yilmaz-Ozden, & Karchmer-Klein, 2017), researchers investigated PTs' TPACK developments within similar course contents.

Haciomeroglu, Bu, and Haciomeroglu (2010) examined the pre-service secondary mathematics teachers' TPACK development in their designs, micro-teaching implementations of GeoGebra integrated lessons, and reflections. In the context of the methods course, PTs were first introduced with GeoGebra and experienced its facilities. Then, they worked collaboratively with peers to design worksheets and discussed on the pedagogical and content related dimensions of their designs. Most of the designs consisted dynamic activities and most of these were student-centered activities. The findings revealed that most of the PTs recommended the use of GeoGebra in teaching mathematics. Authentic experiences in real classroom settings were recommended.

3.2.1.1 Summary of the Approaches for Development of PTs' TPACK in Mathematics Education

The summarized studies presented exemplary interventions within teacher education courses that aimed at both developing and assessing pre-service elementary and secondary mathematics teachers. Besides, there were challenges and limitations reported regarding these interventions. To remedy these challenges and limitations, successful implementation strategies were recommended for designing and implementing teacher education courses in this regard.

Utilization of emerging technologies are powerful in terms of supporting pedagogical strategies in instruction and TPACK framework could be used to support these technologies to reach their potential in teaching (Chai, Koh, & Tsai, 2013). In the literature about development and investigation of PTs’ TPACK presented above, there were examples of utilization of general or content-specific technologies. However, there were few studies in which both technologies were utilized. Moreover, in most of the studies one type of technology was utilized such as graphing calculator (e.g., Meagher et al., 2011; Ozgun-Koca et al., 2010), Spreadsheet (e.g., Agyei & Voogt, 2012), GeoGebra (e.g., Balgalmis, 2013; Durdu & Dag, 2017; Haciomeroglu et al., 2010), Geometer's Sketchpad (e.g., Bowers & Stephens, 2011; Meng & Sam, 2013), virtual manipulatives (e.g., Kurt, 2016) two types of dynamic geometry software (e.g., Akyuz, 2016) and three types of content-specific technologies (e.g., Akkaya, 2016) which limited PTs’ content selections and designs. The studies which limited the content to statistics (e.g., Lee & Hollebrands, 2008) or geometry, also limited the technology types. In addition, in some of the studies, researchers selected certain technologies and trained PTs to develop integration skills regarding those technologies. There were studies in which technology selection was more than three or more (e.g., Mouza & Karchmer-Klein, 2013)

There were studies which offered limited time changing from four to six weeks to develop and assess PTs’ TPACK (e.g., Bowers and Stephens, 2011; Mouza & Karchmer-Klein, 2013; Lee & Hollebrands, 2008; Meng and Sam, 2013). On the other hand, there were courses lasted for a semester which were 14 or 15 weeks and 2 to 4 hours in a week. There were a few studies that employed the research in more than one course (e.g., Mudzimiri, 2012; Niess, 2005).

In the studies reported above, multiple data sources were utilized to assess PTs’ TPACK. Activity designs or lesson plans, video cases, peer, self, and instructor reflections, micro-teaching, self-report surveys, researchers' field notes, and interviews were the data sources. The overall analysis of the related literature showed that emphasis should be on developing and assessing PTs’ knowledge about and application of TPACK which PTs could use in their subject content. However, there were studies which examined TPACK only through self-reports (e.g., Akkaya, 2016). PTs' TPACK can best be identified in their authentic practices. Therefore, most of the studies investigated PTs' TPACK in microteachings or school environments. In the teaching practices that took place in real classrooms (e.g., Balgalmis, 2013; Meagher et al., 2011; Mouza & Karchmer-Klein, 2013; Mudzimiri, 2012), PTs had challenges in implementing their technology integrated lesson plans. The reason was that technology equipments were limited in classroom settings. Therefore, micro-teaching experience was more convenient in this regard.

The participants of the studies in the literature were selected among PTs enrolled in the first year to fourth year. Some of the researchers expressed this as the reason of the low level of TPACK development (e.g., Akkaya, 2016). Therefore, participants of the present study were selected among fourth year PMTs in their last semester in the program who completed pedagogy related courses, method courses, and school observation and simultaneously going to middle schools for teaching practices.

Huang and Zbiek (2016) asserted the need for further research to suggest strategies for developing PTs' technology integration skills in mathematics content courses, methods courses, and field practice courses and for developing PTs' skills for identifying students' learning needs and diverse learning styles. Collaboration and reflection, engaging design activities, and implementing the activities and plans through microteaching were the most frequent and successful strategies used to develop PTs TPACK (e.g., Agyei & Voogt, 2012; Akyuz, 2016; Bowers & Stephens, 2011; Haciomeroglu et al., 2010; Kurt, 2016; Meng & Sam, 2013; Niess, 2005; Cavin, 2008). Integrating the successful strategies reported in the literature, TUME course was designed and implemented to develop and assess PMTs' TPACK-P based on four principles which were transformative approach, collaborative learning, activity-supported learning, and practice-based learning.

3.3 Summary of the Related Literature

TPACK is the teacher knowledge about effective teaching with technology (Mishra & Koehler, 2008). According to integrative view, TPACK is formed of seven knowledge types and their integrations (Angeli et al., 2016). There are studies which investigated PTs' TPACK development through investigating knowledge constructs of TPACK (e.g., Cox & Graham, 2009; Graham, Borup, & Smith, 2012; Jaipal & Figg, 2015). On the other hand, from the transformative view, TPACK is a unified and distinct body of knowledge that goes beyond the knowledge constructs it includes (Angeli & Valanides, 2009, 2015; Koehler & Mishra, 2009; Thompson & Mishra, 2007; Yeh, Hsu, Wu, et al., 2014). From this view, TPACK includes knowledge of context, student needs, pedagogy, tool affordances, content (e.g., Angeli & Valanides, 2009), and knowledge and practices in which PTs utilize technology to enhance students' learning and teachers' instruction (Jen et al., 2016).

TPACK is more than knowledge of technology. To be competent in TPACK, teachers are required to select the effective technologies to support student understanding of a specific content with appropriate pedagogies, design instruction suitable to the teaching environment, and instruct the plan as designed. Therefore, genuine practices should become the focus of context-based studies of TPACK. There is need for discipline-specific examination of TPACK (Baran & Canbazoglu-Bilici, 2015; Chai et al., 2013; Voogt et al., 2013). Graphing calculators (Chai et al., 2013; Ozgun-Koca et al., 2010, 2011), dynamic geometry software (Chai et al., 2013), and virtual manipulatives (Ozgun-Koca & Meagher, 2012) enhance both students' mathematics learning and teachers' implementation. Moreover, using these technologies in teaching mathematics provides building dynamic connections between representations (Ozgun-Koca et al., 2010).

TPACK is an effective framework to design environments which provide opportunity for PTs to gain experiences about utilizing technology (Agyei & Voogt, 2012). TPACK framework serves for preparing PTs for effective integration of technology to teach a specific content to a specific group (Tondeur, van Braak, et al., 2012). Koehler and Mishra (2009) suggested the utilization of the framework for the transformation of the teacher education programs to prepare PTs who are competent in effective technology integration to education by integrating knowledge about and skills in pedagogy, content, and technology. Hence, literature reported many approaches in this regard.

Koehler and Mishra (2005) and Koehler et al. (2007), in Learning

Technology by Design approach emphasized lesson design activities in collaborative environment as an effective strategy. Angeli and Valanides (2005), in ICT-related PCK model, expressed teacher competencies for effective teaching with technology. These were identifying topics, representations and teaching strategies to teach the content with technology; selecting the technology and infusing the technology to the activities. The model was extended and ICT-TPCK Model was proposed by Angeli and Valanides (2009). Peer-assessment and design activities were the strategies that enhanced PTs' TPACK development. As an example of mathematics content-based model, Niess et al. (2009) proposed Mathematics Teacher TPACK Development Model that presented five levels which were recognizing, accepting, adapting, exploring, and advancing. This is an adopted form of a model which specifically directs teachers for mathematics field. In TPACK-Developing Instructional Model (Koh & Divaharan, 2011), PTs were expected to utilize subject-specific technology in their lesson plans to foster teaching and learning. Yeh, Hsu, Wu, et al. (2014) proposed TPACK-P framework as knowledge-based and experience-driven teacher competencies. On the basis of practical use of technology in education, TPACK-P framework proposed four proficiency levels in Assessment, Planning and Design, and Enactment domains (Jen et al., 2016). TPACK is embedded in experience and develops through practice (Yeh, Lin, Hsu, et al., 2015). Deriving from both knowledge- and practice-based nature of TPACK and emphasizing content-specific development, TPACK-P framework is distinctive from the other models of TPACK.

TPACK framework and the other models were used as the base for designing courses that aim at developing technology integration competencies. The studies that consisted course designs implementations based on the principles of TPACK models to develop and investigate pre-service middle school or secondary mathematics teachers were addressed in the previous section. For PTs to professionally incorporate technology into teaching, an environment fostering to investigate technological tools' affordances in mathematics education was prepared for them in the courses. These courses showed positive impact on teachers' effective integration of technology into education (Angeli & Valanides, 2009; Chai et al., 2010). Researchers attempted to enhance PTs' TPACK in mathematics by redesigning methods courses (Haciomeroglu et al., 2010; Lee & Hollebrands, 2008; Meng & Sam, 2013; Ozgun-Koca et al., 2010), teaching practice courses (Agyei & Voogy, 2012; Balgalmis, 2013), mathematics courses (Durdu & Dag, 2017; Kurt, 2016; Meagher et al., 2011), many of these courses concurrently (Mudzimiri, 2012; Niess, 2005) or designing new courses (Akkaya, 2016; Akyuz, 2016; Bowers & Stephens, 2011; Cavin, 2008). The present study was conducted by designing and implementing the TUME course with effective strategies as suggested in the related literature. The principles of the TUME course reflect these effective strategies.

Course designs contextualized in TPACK principles yielded positive influences on technology integration competencies of PTs (i.e., Angeli & Valanides, 2009; Chai et al., 2010; Jimoyiannis, 2010) and effective strategies for teacher education course designs were expressed in these studies in terms of content and instructional strategies which aim at development of PTs' TPACK. For instance, linking theory with practice, learning technology integration by designing, the teacher educator being the role model, and working collaboratively with peers were among the 12 key themes Tondeur, van Braak, et al. (2012) identified as the characteristics of effective interventions of teacher education programs for PTs' preparation for technology-integration in their teaching practices. Continuous feedback is supportive and effective in terms of enhancing technology-integration skills (Niess, 2005; Tondeur, van Braak, et al., 2012).

Collaboration provides opportunity for PTs to share and develop abilities and attitudes within groups (Tondeur, Scherer, et al., 2017). Within collaboration, sharing ideas, feedback, discussing and sharing with peers, and peer-interaction enhance TPACK development (Agyei & Voogt, 2011; Jang, 2008b; Tondeur, Roblin, et al., 2017). It is effective for PTs to feel self-competent when they work together and participate actively within the groups while designing technology-supported materials that meet curriculum objectives (Angeli & Valanides, 2009; Lee & Lee, 2014; Mouza et al., 2014). Hence, collaborative design environments support development of TPACK (Koehler & Mishra, 2005; Koehler, Mishra, & Yahya, 2007, Polly et al., 2010; Tondeur, van Braak, et al., 2012).

TPACK develops through practice for being a situated and practice-based knowledge. PTs should engage in technology-facilitated designs to develop TPACK (Agyei & Voogt, 2012). Practical knowledge is a developing knowledge centrally related with actions, people, and contexts in that teacher education programs should provide continuous development and authentic experiences (Yeh, Hsu, Wu, et al., 2014). PTs' TPACK needs to be examined in practice that the lesson plans should be considered with the implementations (Mouza & Karchmer-Klein, 2013). TPACK-P model was proposed as a practice-based TPACK approach. Experience-driven methodology is needed to elicit PTs' TPACK embedded in their practices (Yeh, Lin, Hsu, et al., 2015).

This study is unique for comprising distinctive features emphasized in the literature in one context. PMTs' TPACK-P was aimed to be developed in a technology-enhanced course which was designed based on TPACK-P principles with a transformative view towards TPACK. The evidences of TPACK-P were investigated through data sources that provided both perceived and observed TPACK-P of PMTs'.

CHAPTER 4

METHODOLOGY

The purpose of this study was to enhance and investigate pre-service middle school mathematics teachers' (PMTs') TPACK-P development through the Technology Use in Mathematics Education (TUME) course. Answers to the following research question and two sub-questions were sought throughout the study:

1. How does the Technology Use in Mathematics Education Course influence pre-service middle school mathematics teachers' TPACK-P development?
   a) What are pre-service middle school mathematics teachers' TPACK-P proficiency levels in the beginning of the Technology Use in Mathematics Education Course?
   b) What are pre-service middle school mathematics teachers' TPACK-P proficiency levels at the end of the Technology Use in Mathematics Education Course?

In this chapter, context, research design, participants of the study, data collection procedures, data collection instruments, and data analysis procedures were explained in detail. In addition, strategies to prevent possible threads to internal validity and reliability, limitations of the study, and ethical considerations were addressed.

4.1 Research Design

The intention of the research, which was to investigate PMTs' TPACK-P development in detail throughout a course about integrating technology to mathematics education, led to a qualitative design. Qualitative research strategies were used to collect and analyze the data to reveal PMTs' TPACK-P development. This study was a single-case study with a holistic design. In a case study design, researchers explore a case, process, activity, program, event, individuals (Creswell, 2013), decisions, programs, and/or implementation process and conduct in-depth analysis of multiple data sources (Yin, 2013). The holistic single-case study design refers to a single experiment with a single unit of analysis including no embedded sub groups and having a holistic nature (Yin, 2003). Hence, the case in the present study was the group of PMTs who were 11 senior-level Elementary Mathematics Education (EME) Program students enrolled to the undergraduate course TUME.

The reason for using case study approach in this study was to be able to make detailed investigation and observation from various perspectives in order to reveal PMTs' TPACK-P progress through the course by seeking answers for whys and hows of their views on and use of technologies. In order to answer the research question about PMTs' TPACK-P development, the researcher looked for answers of several questions such as why they selected to use certain technologies with pedagogical strategies to teach specific mathematical concepts; what they thought about technology use in mathematics education and about affordances and constraints of technologies; and how they designed and enacted technology integrated mathematics courses.

In this study, PMTs' TPACK-P development was limited to the semester and to the content of the TUME course. In the context of the TUME course, the data were collected from multiple sources in order to provide a complete understanding of PMTs' TPACK-P development. The data were collected via questionnaires, pre and post lesson plans, observations, researcher's field notes, micro-teaching, self-assessments, and face-to-face semi-structured interviews. In the end, the researcher investigated PMTs' TPACK-P development from multiple perspectives to elucidate the issue in a larger detailed picture. PMTs were investigated in the natural context of the TUME course at the university. In the data collection process, according to PMTs' behaviors and development of TPACK-P through the study, the researcher focused more on the reasons of participants' use of the technology and their views about technologies by frequently asking for their feedback. The emergent design was due to the flexible nature of the qualitative approach. In addition, researcher's familiarity with the subject and experience in the field directed the research process and interpretation of the data. According to Yin (2009), researcher's position moves a case study to the right direction and eliminates focusing on other distracting information. The researcher was the key instrument as being both the instructor of the course and the first-hand data collector in all steps of the study.

4.2 The Context: Elementary Mathematics Teacher Education Program

The study was conducted in Elementary Mathematics Education (EME) Program under the Department of Elementary Education in the Faculty of Education at a private university in Ankara, Turkey. EME is a four-year bachelor's degree program training PTs to be mathematics teachers for middle schools (grades 5 to 8). These programs last for 8 semesters and consist of 54 courses with a total of 240 credits of European Credit Transfer and Accumulation System (ECTS). The Higher Education Institution in Turkey determines the compulsory courses of the program which refers to 206 ECTS. The faculties only have the authority to determine the elective courses of 34 ECTS. The program offers courses on mathematics, mathematics teaching and learning, and practicum. Students can also take general, cultural, and educational knowledge elective courses. The list of courses in each semester were provided in Appendix A. Lessons are carried out theoretically and practically in the program. The TUME course was planned and designed by the researcher and offered as an elective course with 5 ECTS. This program, similar to all university departments in Turkey, accepts students according to their scores on the national university entrance examination which is carried out annually. Only the students in their last year of high school education or graduated from the high school can take this examination.

4.3 Participants

Turkish EME Programs at Faculties of Education aim to train mathematics teachers for teaching middle school mathematics. Participants were selected among the senior students in their last semester at the EME Program of Elementary Education Department at a private university in Ankara, Turkey. PTs in the EME program had completed compulsory and elective courses of 210 ECTS at the end of the seventh semester. In their last semester, they enrolled to three compulsory and two elective courses. Eleven PTs were enrolled in the elective TUME course at the Spring semester of the 2015-2016 academic year. The other four courses they attended simultaneously were Fundamental Concepts in Mathematics Education (8 ECTS), Turkish Education System and School Management (4 ECTS), School Practice (9 ECTS) as the compulsory courses and Diction (4 ECTS) as the other elective course.

Purposive sampling helps to gain rich data to investigate the research interest (Creswell, 2013). Of the 17 seniors in the EME program, 11 seniors who enrolled to the five-credit elective TUME course in 2015-2016 academic year composed the participants of this study. They were ten female students and one male student whose ages ranged from 21 to 27. These 11 PMTs at their last semester in the EME Program served the purpose of the research for several reasons. First of all, they had completed 50 out of 54 courses in the program which made them qualified in the mathematics education courses, pedagogical courses, and cultural, field specific, and educational elective courses. Hence, they were familiar with pedagogical strategies; they had completed courses about basic computer skills, revised the curriculum more than once, and observed mathematics courses at a middle school for one semester. Moreover, in the same semester with the TUME course, they were taking the Teaching Practice course. In the context of that course, they were practicing at a middle school where they were gaining experience in an authentic environment about classroom context, mathematics instruction, student characteristics, time and classroom management, and other aspects of mathematics teaching and learning process. Teaching Practice course was a compulsory course for EME Program in which PMTs observed mathematics courses in a public middle school for six hours a week for 14 weeks. In addition, they taught a minimum four mathematics courses in the context of this course. Knowing the conditions about mathematics teaching and learning in the middle school context was compulsory to experience, design, and implement technology supported mathematics instruction effectively. Therefore, they had essential background to learn for and from practical experience in terms of TPACK-P.

The group was also convenient to study with. The researcher had access to and familiarity with the University she was working at and the students of the university. Therefore, the study was conducted at the University's EME Program at the Faculty of Education and the participants of the study were volunteering seniors in the program. Moreover, the researcher designed and offered the course. Therefore, she had the control of the content and the flow of the course.

4.4 Data Collection Procedure

Data collection process covered three stages. In the first stage, at the beginning of the semester the data were collected to determine PMTs' initial TPACK-P levels before they attend the TUME course derived from their perceptions towards teaching profession, experience in technology use in education, and their technology-integrated lesson designs. In the second stage, participants were supported for one semester throughout the TUME course to enhance their TPACK-P development through the activities and assignments in the context of the course. In the last stage, individual interviews were conducted after the course ended. In this section, researchers' role in the study, the content of the TUME course, and the data collection sources used in the three stages were explained thoroughly.

4.4.1 The Role of the Researcher

The researcher had been working as a research assistant at the EME Program at the Faculty of Education in a private university for eight years at the time of the study. She was familiar with the faculty and the students in the Department of Elementary Education. Researcher's past studies were also on educational technologies. In her master's thesis, she investigated PMTs' use of graphing calculators in teaching algebra in middle school. Therefore, conducting a study with one educational technology led to intentions for conducting a study with a range of technological tools. Hence, there was a connection between researchers' academic background, research interests, and the intention of the present study.

The researcher was the instructor of the TUME course which positioned her as a participant-observer. The participant-observer role enabled the researcher to control the direction of the study, to organize the course, and to observe participants both with the instructor and the researcher views. Senior level PMTs who enrolled to the course were familiar with the researcher since their first year in the Program either as their instructor or as their graduate assistant in several courses. It is believed that PMTs' familiarity with the researcher formed a relaxed course environment in which PMTs were comfortable in expressing their ideas within the class, in their reflections, discussions, group works, and in the individual interviews conducted after the course.

4.4.2 Technology Use in Mathematics Education (TUME) Course

As it was stated by several other studies mentioned in the previous chapter, this study relied on the assumption that PMTs can progress their TPACK-P through a course where they not only learn about technologies, but also integrate technologies with pedagogies through designing and enacting technology supported instructions to enhance mathematics teaching and learning. Connecting this proposition, TUME course for developing TPACK-P was designed and PMTs' TPACK-P development was investigated through that course.

The general purpose of the TUME course was to prepare future teachers who are competent in effective technology integration in mathematics education. In this mathematics discipline-focused course, it was aimed to provide PMTs with the opportunity to develop skills in and knowledge of using technology in designing and instructing middle school mathematics courses. To achieve this aim, PMTs explored, examined, practiced, and adapted educational technologies throughout the TUME course. The educational technologies in the course were selected among current, frequent, and effective educational technologies that were suggested to be used in middle school mathematics education in Turkey and all over the world in the related literature. Besides, based on the content of the course, PMTs were also updated by pedagogical strategies for technology integration and the content of middle school mathematics curriculum in Turkey.

The setting of the course was the mathematics laboratory at the Faculty of Education (see Appendix B). In the mathematics laboratory, there were 6 round desks each for 5 people which supported collaborative and group work. There were material cabinets filled with mathematical materials, posters, and stationary. Moreover, the mathematics laboratory was equipped with a computer for the instructor and a projector connected to the computer. Some course hours were spent in the computer laboratory where each participant could have his own computer. Providing each participant with one computer enabled participants to engage individually in GeoGebra program, poster preparation programs, online games, and virtual manipulatives.

TUME course was planned and designed based on TPACK-P framework suggested by Yeh, Hsu, Wu, et al. (2014). The course with all its components was intended to carry the characteristics of TPACK-P model (i.e. Jen et al., 2016; Yeh, Hsu, Wu, et al., 2014; Yeh, Chien, Wu, et al., 2015). In their subsequent studies, Jen et al. (2016) proposed four levels of competency regarding teachers' TPACK-P. The researcher formed a coding scheme with the benchmarks and indicators for each level. The highest level considering TPACK-P was reflective application level corresponding to level 4. The TUME course objectives were based on the indicators of reflective application level shown in Table 4.1 (Jen et al., 2016, p. 49).

As proposed by Jen et al. (2016), the indicators in Table 4.1 were identified for three teaching domains which are i) assessment, ii) planning and designing, and iii) enactment. In TPACK-P competency levels, a teacher should accomplish the eight indicators in order to reach level 4. The two indicators for assessment are about evaluating student knowledge both before and after teaching. The four indicators in planning and designing refers to teachers' competency and skills in designing technology enhanced courses by adopting appropriate teaching and learning strategies to improve diverse student learning. The two indicators for enactment regards implementing technology assisted courses where technology is used efficiently to meet individual student needs in a student-centered environment and constructing instructional materials with technology that serve for different instructional purposes (Jen et al., 2016).

Table 4.1

Indicators of Level 4: Reflective Application

Domains	Indicators
Assessment	1. Be able to use various representations or ICTs in instruction that enables teachers to identify students' learning styles and learning difficulties (e.g., cognitive, affective) for the preparation of adaptive instruction. 2. Be able to construct technology-supported assessments through which students' knowledge of and about science can be evaluated.
Planning and designing	3. Be able to utilize functions of technology to facilitate teachers' (their) and students' exploration of scientific phenomena and construction of their science knowledge. 4. Consider and design technology-supported curricula for the purpose of enhancing students' learning of and about science with skillful use of technology. 5. Be able to construct technology-supported curricula based on students' prior knowledge or for purposes of inquiry learning, with strategic uses of digital representations or ICT tools. 6. Be able to use student-centered instructional strategies to accommodate students' learning of and about science inquiry-based tasks in technology-supported environment.
Enactment	7. Be able to use a variety of technology flexibly and strategically to accommodate students' different learning needs, support their knowledge construction, and improve instructional effectiveness. 8. Be able to customize instructional materials with skillful uses of technology or multimedia resources for different instructional purposes.

Note. Reprinted from "Science Teachers' TPACK-Practical: Standard-Setting Using an Evidence-Based Approach," by T. H. Jen, Y. F. Yeh, Y. S. Hsu, H. K. Wu, and K. M. Chen, 2016,*Computers & Education*, *95,* p. 49.

In order to reach the Reflective Application level, TUME course was designed, planned, and implemented based on the following principles driven from TPACK framework (Koehler & Mishra, 2008, 2009) and TPACK-P framework (Yeh, Hsu, Wu, et al., 2014; Yeh, Chien, Wu, et al., 2015): Transformative approach, collaborative learning, activity-supported learning, and practice-based learning. The definition and adaptation of these principles in TUME course were explained below.

Transformative approach: From the transformative view, TPACK is a unified knowledge that extends beyond its components (Angeli & Valanides, 2005, 2009). From this point of view, the TUME course was built on the composition of TPACK-P components. These components are examining the role of technology in mathematics education, investigating educational technologies and technology integrated teaching and learning strategies, regenerating mathematics courses by infusing educational technologies, and reflecting on these issues from a distinct perspective of transformative approach.

Collaborative learning: Collaborative work in designing technology-enhanced teaching materials enhances development of TPACK (Koehler & Mishra, 2005; Koehler et al., 2007; Polly et al., 2010; Tondeur, van Braak, et al., 2012). Moreover, collaborative work empowers designing high level quality materials suitable for practical use (Yeh, Hwang, & Hsu, 2015). Therefore, teaching, thereby learning, in the TUME course was designed on a collaborative principle. Collaborative environment offered participants to exchange ideas, experience, and skills. Moreover, interacting with and gaining from each other while designing technology integrated products in each activity and discussion was an important consideration. While working on designing learning products in every activity in the second part of the course, discussions held within groups led participants to create a common view from diverse views within a group. Following the group discussions, whole-class discussions provided opportunity to criticize the opposing or different views.

Activity-supported learning: Activity-supported learning enhances development of TPACK which is learning to plan effective technology supported instruction in the context of curriculum (Harris & Hofer, 2009) and thereby TPACK-P (Yeh, Chien, Wu, et al., 2015). Moreover, activity-supported learning shifts the focus from teacher-centered approach to student-centered teaching (Agyei & Voogt, 2012). In each activity, participants conducted research on the given topic in the scenario. They gathered information about the technology, its affordances, and sample uses. Then, they searched learning goals in the mathematics curriculum and the misconceptions about the mathematical subjects. Finally, they analyzed and synthesized this information to form a technology-supported learning product.

Practice-based learning: TPACK-P is a knowledge construct that educators can develop for using in practice from their own practices with technology and it can only be improved through practical usage of technology (Jen et al., 2016). Although knowledge of pedagogical strategies, technological tools, and content are required for TPACK development, the essential focus should be on "learning or actual uses of technology to support different instructional purposes" (Jen et al., 2016, p. 57). Accordingly, practice-based content of the TUME course aimed at developing and strengthening participants' TPACK-P through interaction with technologies, engaging technology-enhanced activities in a supportive environment, and creating and implementing technology-integrated designs as suggested by Jen et al. (2016). Thereby, practice lied behind all activities, discussions, and assignments in the TUME course. Both course activities and the micro-teaching assignment were teaching practice experiences that provided opportunities to participants for transforming their theoretical knowledge into practice.

Table 4.2

The Content of the TUME Course

The Parts of the TUME Course	Content
Part 1: TPACK: Theoretical Background (3 weeks)	Technology use in mathematics education Educational technologies FATIH project TPACK framework Research in TPACK
Part 2: Educational Technologies: Investigating, Designing, and Reflecting (8 weeks)	Examination of general technologies and mathematics field specific technologies Social network for teachers The role of technology in evaluating teaching and learning Planning and designing technology supported mathematics courses
Part 3: Integrating Technology into Mathematics Education (3 weeks)	Micro-teaching

The TUME course was designed considering the principles explained in detail above. An overview of the content of the TUME course was presented in Table 4.2. As shown in Table 4.2, the course was consisted of three following parts mainly; 1) Theoretical background of TPACK, 2) Educational technologies: Investigating, designing, and reflecting, and 3) Integrating technology into mathematics education. The course lasted for one semester of 14 weeks. There were 3 course hours in a week and 42 course hours in total in the semester. The course syllabus was presented in Appendix C. In the following three sections, the content of the three parts of the TUME course was explained in detail.

4.4.2.1 First Part of TUME Course: Theoretical Background of TPACK

In the first part, the first three weeks, theoretical background about using educational technologies in mathematics education and TPACK framework were examined and discussed. PMTs were briefly informed about the current educational technologies, technology use in mathematics education, TPACK framework, recent studies about development of teachers' TPACK, technology related standards of NCTM, NCATE, ISTE, and national curriculum in Turkey, and FATIH Project, current trends in technology use in education, and methods and approaches about effective technology integration in education.

To inform the participants about these titles, book chapters and articles about the review of TPACK framework and the studies conducted based on the framework were weekly assigned to the participants (see Appendix C). As the participants did not have sufficient English language skills, the books and articles and books were selected in Turkish. Selected studies and applications of technology enhanced education in all science areas were reviewed in the context of the course. Additionally, discussions were held about the facilities of educational technology applications in classrooms.

4.4.2.2 Second Part of TUME Course: Educational Technologies: Investigating, Designing, and Reflecting

The content of the course provided an environment for PMTs to investigate both educational technologies and mathematics discipline-specific technologies.

That is, throughout the eight-week long second part of the course, participants met general and content specific educational technologies and discussed on the issues related with educational role of the technologies. The researcher selected technologies that were commonly used in education for being effective, functional, user friendly, and preferably free. The list of these technologies and the discussion topics are given in
Table 4.3.

Table 4.3

Educational Technologies: Investigating, Designing, and Reflecting

General technologies	Visual sharing platforms Concept map preparation applications Poster and infographic programs Assessment: constructing quizzes and student reflection systems Video editing applications Course platform
Mathematics field specific technologies	Interactive math games Dynamic environments Smart Boards
Discussion topics	Social network for teachers The role of technology in evaluating teaching and learning Planning and designing technology supported mathematics courses

While some of the selected technologies were compatible to be used in every field of education, the others were specific to mathematics content. In the beginning, participants investigated educational technologies which were adaptable to teaching and learning of all fields of science. For visual sharing websites, Flickr and Pinterest; for preparing concept map, Inspiration; for assessment and constructing quizzes, Socrative and Kahoot-it; for preparing poster and infographics, Piktochart and Glogster, and for video editing, Video Show and Inshot Viva Video were introduced as the sample programs among many other similar functioning programs. In addition to the discipline-free educational technologies, the course consisted of technologies specific to mathematics education which were Construct 3D, Vector Grapher, and zSpace Euclid's Shapes for augmented and virtual reality, GeoGebra, Desmos, and Cabri 3D for dynamic environments, ClassPad for graphing calculators, and selected websites for online mathematics games and virtual manipulatives. In addition to these technologies, participants experienced using three types of Smart Boards in the Faculty classrooms and in an authentic context in a mathematics course at a middle school.

The technology introducing weeks, which was the second part of the TUME course, was different from other parts of the course in terms of design. There was a three-step implementation in investigating each educational technology. The steps were 1) introducing the technology, 2) connection with education, and 3) reflecting on the technology's role in teaching middle school mathematics.

In the first step, the researcher introduced brief tutorials including the technology's features, its educational affordances and presented sample applications. Then, for the second step, participants experienced the technology by exploring it on their own. After getting used to the features of the technology, participants engaged in the group activities that the researcher planned beforehand. Although each activity had its own scenario, the common context mainly required participants to investigate the affordances of the related technology and match these affordances with the objectives in the middle school mathematics education curriculum in Turkey. The activities required participants to determine objectives from the curriculum that could match the technology's affordances.

Then, for the goals participants selected from the curriculum, the researcher motivated them to plan an alternative instruction design via the help of the week's technology. They were also asked to design materials and activities that can be used in teaching several middle school mathematics subjects. Participants worked within groups as directed in the instructions. When completed, groups presented their product of technology supported materials and designs at the end of each activity. In the final step, discussions were held within and among groups about their designs referring to the utilities and deficiencies of the technology in terms of middle school mathematics education. They mentioned the role they gave to the technology and justified their selection of the pedagogical strategies in relation with the particular mathematics content in their groups' design.

The researcher selected five weeks to gather participants' written views about the weeks' technologies. Participants reflected on their experiences with educational technologies that they met in the technology weeks. They provided answers to five open-ended questions that required answers blending pedagogy, the technologies introduced in the related week, and middle school mathematics content. Two researchers with doctoral degrees in the field of mathematics education who had research articles about technology use in education reviewed the questions in terms of TPACK-P framework. The questions were finalized accordingly. They answered the questions digitally by sending a message or e-mail via their mobile phones. Each reflection session took approximately 10 minutes. The evaluation questions were as follows:

1. Can you describe your experiences with the educational technology?
2. What are the affordances of the educational technology?
3. What aspects of the educational technology should be improved?
4. Would you prefer to use this educational technology as a teacher? Why?
5. In which grades and subjects would you suggest the use of this educational technology? Please specify objectives from the curriculum.

While providing answers to the questions, participants gained the role of an educational expert and criticized the utilities and feasibilities of the educational technologies. In addition, the questions led them to discuss the place of the particular technology as a supportive tool matched with appropriate pedagogical strategies when teaching a particular middle school mathematics subject in the educational setting. This assignment was aimed at contributing to their TPACK-P development by motivating them to think about the affordances and constraints of several technologies and about the pedagogical strategies to empower the affordances in relation with middle school mathematics content.

In addition to introducing educational technologies in the second part of the course, participants' knowledge on middle school mathematics content was refreshed with quick curriculum revision sessions every week. Pedagogical approaches for technology integrated mathematics teaching were also investigated thoroughly. They were introduced with instructional designs that can be incorporated with technologies. The last week of this second part of the course was spent on examining the technology integrated sample plans in mathematics education and discussing them thoroughly in terms of knowledge dimensions of TPACK, namely technology, pedagogy, and content.

The educational technologies that were covered in the second part of the TUME course are explained in detail below. They were explained within the activities conducted in the class hours.

4.4.2.2.1 Educational Technologies and Related Activities in TUME Course

In the second part of the TUME course, participants engaged in 10 activities. PMTs were assigned these pre-designed activities that were prepared for their development of technology integration skills and practical use of these technologies in mathematics education. Participants were given opportunities to practice each technology in various activity contexts designed for and defined in middle school settings. Discussions and reflections led participants to investigate how technology can be transformed for educational aims and be utilized in teaching mathematics to promote different instructional needs. The course activities and the related educational technologies were presented in Table 4.4.

Table 4.4

Technology Activities in TUME Course

	Activities	Technologies
1	Exploring mathematics activities	Flickr and Pinterest
2	Exploring concept maps	Inspiration and Mindly
3	Creating educative posters	Pictochart, Glogster, and Powerpoint
4	Constructing mathematics	GeoGebra, Cabri 3D, and Classpad
5	Evaluating student learning	Socrative and Kahoot-it
6	Exploring Smart Board in authentic setting	Smart Boards
7	Vlogger video recording	Video Show
8	Interactive game competition	Online platforms for math games and virtual manipulatives
9	Designing lesson plans via TPACK game	All technologies
10	Posting on the online course platform	Facebook

The activities listed in Table 4.4 were meticulously prepared cognitive tasks addressing TPACK-P objectives. In the procedure of completing the activities, several opportunities were given to PMTs to engage in, practice, and reflect on educational technologies where they were encouraged to (i) think, plan, and redesign technology infused instructional activities and (ii) provide reasons for the practical use of the design in a middle school mathematics course (Yeh, Hsu, Wu, et al., 2014). This environment was provided to foster PMTs to rethink and reconceptualize middle school mathematics content through utilization of technology.

In the activities, participants firstly gained general information about the use and features of the technology from the instructor; secondly investigated the affordances of the technological tool; thirdly searched the middle school mathematics curriculum goals, and selected the goals that the technology would enhance learning and meet the instructional needs of that goal, and lastly designed a learning material or an activity. Collaborative group work and all-class discussions afforded participants opportunity to develop and share ideas about the recently introduced technology. Activities were designed by the researcher except Activity 10. The instructions, application process, and details about the activities were explained thoroughly below.

Activity 1: Exploring mathematics activities

The aim was to enlightening participants in terms of online shared materials all over the world such as posters, concept maps, and activities in several mathematics topics. They downloaded the mobile application of Pinterest and Flickr visual sharing websites for this search. Moreover, in the context of this activity, the researcher instructed about social networks for teachers and participants searched relevant websites.

Activity 2: Exploring concept maps

Participants selected a topic in which a concept map would enhance learning. They sequenced the concepts in the mathematical subject. They also determined which part of the course they planned to use the concept map and for which reason. They worked on Inspiration and Mindly programs on the computer. They were not asked to prepare a concept map since they did it in Computer I and Methods I courses. Instead, they searched for and selected effective and extensive concept maps online, commented on the strong and weak parts of those maps, and provided ideas as a group to improve them.

Activity 3: Creating educative posters

This activity was about preparing posters and infographics by Piktochart, Glogster, or Powerpoint poster preparation programs on the computer. The instructions involved searching middle school objectives that infographics and posters could evoke misconceptions and designing one to preclude or remedy them.

Activity 4: Constructing mathematics

Casio ClassPad 330 is a handheld device that embodies graphical representations, algebraic representations, and data tables while linking these representations. In the course, the online application of the graphing calculator was used. Participants downloaded Casio ClassPad 330 application on their mobile phones and computers. The dynamic environments GeoGebra and Cabri 3D were also used on the computer. The aim of the activity was to construct geometrical figures and relate the algebraic, graphical, and tabular representations. In the context of the activity, participants made extensive online research and shared the effective uses of these technologies in mathematics in the course. Finally, they searched the curriculum and selected goals to improve teaching and learning through GeoGebra. Then, groups generated and presented activities with GeoGebra.

Activity 5: Evaluating student learning

The activity was about assessment of teaching and learning. The activity involved constructing quizzes via Socrative and Kahoot-it applications. Moreover, selected groups applied their quizzes to other students in the classroom. At the end of the activity, the role of technology in evaluating teaching and learning was discussed thoroughly. The researcher provided participants with related research and samples about this issue.

Activity 6: Exploring Smart Board in authentic setting

Participants experienced two types of Smart Boards for this activity. One was Classic 2810 version of PolyVision brand situated at the computer laboratory in the Faculty of Education. Participants experienced the Smart Board features on this one and used it as if they were teaching in a middle school mathematics classroom. They set the Smart Board ready for the course, opened and created files on it, made changes on the files, experienced the features of the drawing and editing buttons on its side and turned the Smart Board off. In addition, PMTs visited a private middle school in the neighborhood where Smart Board 800version of Smart brand was equipped. In the school, Smart Boards were equipped in all classrooms and teachers were using them in all courses. Before the visit, the researcher arranged an appointment with one of the mathematics teachers at the middle school. The teacher was at the beginning of the Transformations subject in 7^{th} grades. Without affecting the flow of the course, the researcher and the mathematics teacher planned a two-hour course where GeoGebra and basic features of the Smart Board were used. PMTs observed this middle school mathematics course implementation via Smart Board. After that course, they had the opportunity to use the Smart Board and ask questions to the mathematics teacher.

Activity 7: Vlogger video recording

Video Show mobile application was introduced to the participants. They experienced the menus and features of the application. Within the scope of the Vlogger Video Recording activity, the researcher gave a problematic scenario to each participant in which an imaginary middle school mathematics teacher was expressing his teaching problem of a particular subject (See Appendix D). There were two problems in each scenario which were pedagogy and content-based problems in middle school contexts. An example of a pedagogy-based problem was “Students solve the operational problems about rational numbers by following the rules of operations. They do not understand the relationship between rational numbers and a whole. How can I guide them in these issues?” An example of a content-based problem was “I cannot engagge all of the students in the discussions. How can I enhance their active participations to the lessons?” The contents of all scenarios included similar situations.

Scenarios were numbered from 1 to 10 and each participant selected one number randomly. One scenario was selected twice. The two participants who selected the same scenario were put in separate groups. Participants worked in groups of two or three to find alternative solutions with the support of educational technologies to the teaching problems presented in the scenarios belonging to middle school mathematics context. Each participant was expected to shoot a famous video that would receive a million clicks in a video sharing website. Hence, the aim was to motivate groups to develop solutions that were informative, applicable, creative, and attractive which suited to be a vlogger video. In this collaborative work in groups, participants were instructed to provide technology supported solutions to authentic instructional problems in the scenarios and work together in preparing their videos.

The aspects that should be included in the context of the video were a) the goals in the curriculum related to the mathematics topic, b) the background mathematics knowledge related to this topic, c) parts of the lesson plan that will be focused in the suggestion, d) technology suggestion that will be best to overcome the problem, and e) pedagogical strategy that will integrate effectively with the suggested technology. Moreover, they were given a list of contextual principles some of which were about considering individual student needs, crowded classrooms, and misconceptions on the specified mathematics concept.

Activity 8: Interactive game competition

Participants made extensive online research of websites for online mathematical games and virtual manipulatives. The groups selected the most effective game and/or virtual manipulative to improve mathematics learning and shared the game in the course Facebook page, which was explained below. Moreover, groups competed at the selected games and the winner was determined.

Activity 9: Designing lesson plans via TPACK game

This activity was about planning and designing technology supported mathematics instruction. In this respect, before the activity, sample technology infused mathematics plans were examined with the guidance of the instructor and they were discussed in terms of components of technology, pedagogy, content, context, and availability into practice.

The TPACK game, developed by Richardson (2010), is about designing instruction according to the items coming from technology, pedagogy, and content pools. In the context of this activity, the researcher prepared the items of the pools. The technology pool included various technologies extending the ones mentioned in the context of the course such as Wikibooks and Sketchpad. The content pool included all learning areas mentioned in the Turkish Middle School Mathematics Curriculum (MoNE, 2013) from 5th to 8th grade. The pedagogy pool included the instructional techniques that participants had learnt in a relevant course. The items of the pools were reviewed all together with the participants to prevent any misunderstanding about the items.

In the TPACK game, participants worked collaboratively in three groups. Two groups included four and one group included three participants. All groups had three cups with same items written on piece of papers. As applied in a study (i.e., Baran & Uygun, 2016), participants played the game in 4 different tours. In three of the tours, one item from one of the technology, pedagogy, and content pool was selected non-random and the rest of the items were randomly selected from the pools. In the fourth tour, all items were randomly chosen from the pools. After selecting random items, participants decided on the non-random item. Then, they made research and brainstormed their ideas for integrating the three domains and came up with the best design. Discussions were held when participants reflected on the designs and criticized the affordances and constraints of the designs in terms of middle school context and feasibility in practice.

Activity 10: Posting on the online course platform

At the beginning of the semester, all participants were enrolled to the course platform on Facebook named as Technology Use in Mathematics Education Group. There were several reasons for forming an online accessible course platform. First and foremost, participants were able to engage with peers and the instructor not only in the course hours, but throughout the week. Secondly, participants had opportunity to experience each other’s in-class works and share ideas on Facebook course page. This was considered essential that they might miss seeing other works in class, or miss listening to others' ideas and stating their views in the classroom discussions. The online course platform provided them a discussion environment outside of the classroom beyond the class hours. It also provided a visual archive for participants which gathered their works together in an online page through the semester. Furthermore, the data gathered in the Facebook page were planned to be used in the interview process as a recall to participants about their group products and individual posts.

On the Facebook course page, participants were required to post about the topic of each week. These posts were the products of the activities prepared by the groups weekly. In addition to their classroom products, they were asked to find and share online learning materials such as articles, blog posts, news, and any post they found worth to share about technology use in education. Moreover, they were assigned to comment on at least two of others' work. Weekly assignments such as readings were also announced via the platform. The classroom page served as the schedule and place to present products of weekly topics. The aim was to maintain the collaborative environment outside of the classroom. Participants engaged in discussions with their peers in the context of their posts.

4.4.2.3 Third Part of TUME Course: Integrating Technology into Mathematics Education

In the last three weeks, which was the third and the last part of the course, participants were encouraged to plan, design, and enact a technology integrated mathematics course. As shown in Table 4.5, this was the final assignment of the course in which participants were instructed to prepare a technology integrated lesson plan, present it to the instructor, finalize the plan according to the instructor's suggestions, and implement the finalized lesson plan via micro-teaching in class.

Presenting lesson plan through micro-teaching was decided for two reasons. First, the micro-teaching assignment was an opportunity for the application of TPACK knowledge through designing and enacting lesson plans. The participants had the opportunity to apply their skills in practice where their peers were the students. It was considered important both to receive and to provide feedback for peers since peer-learning was considered to be useful to build on each other's work and develop their TPACK (Angeli & Valanides, 2009; Tondeur, van Braak, et al., 2012).

Table 4.5

Integrating Technology into Mathematics Education

The Content of TUME Course	Technologies
Designing lesson plans Micro-teaching	Not restricted

The other reason was that participants were going to be restricted in terms of technology if they were to implement their lesson plans in the middle schools in the neighbourhood or in their practice schools. The initial plan was to implement the lesson plans in the schools which they were simultaneously visiting in the context of Teaching Practice course. However, after they prepared the lesson plans, all participants articulated the poor technological facilities and lack of essential infrastructure in the middle schools to implement their lesson plans. In the middle schools they were practicing at, mobile phone use was forbidden, too. If they were assigned to implement at the middle school anyway, the content of the lesson plans would have to be changed, which was contrary to the aim of the research. Therefore, PMTs conducted micro-teaching in the TUME course.

Participants were assigned to design and plan one class hour mathematics course and were given a brief list about the lesson plan outline avoiding a stereotype outline and the micro-teaching instructions. The instructions they should consider while designing the lesson plan were constructed by combining the principles of TPACK-P (Yeh, Hsu, Wu, et al., 2014; Jen et al., 2016) and the aspects of technology-infused activities designed for authentic settings (Papert, 1997). These instructions were provided below.

i. Determine a problematic middle school mathematics concept relying on the relevant previous research.

ii. Define the learning outcomes of the subject relying on the national middle school mathematics curriculum.

iii. Explain the school and classroom context where you will teach.

iv. Select technologies that will best serve to enhance teaching and learning of the selected subject.

v. Modify selected technologies to become educational technologies serving for educational purposes about teaching and learning of the selected topic.

vi. Prepare technology integrated activities that will serve for solving the existing misconceptions or preventing the possible misconceptions in the selected subject and enhancing learning of the selected subject thoroughly.

vii. Decide on the appropriate pedagogical approaches that will best integrate with the activities to the selected subject.

While preparing the lesson plans, they were asked to design a course to reach the goals at the national middle school mathematics education curriculum. They were not limited in terms of technology types and number of technology they should use. Instead, they were allowed to choose from a wide range of both general and content-specific technological tools. Participants designed lesson plans and performed micro-teaching in Methods I, Methods II, and School Experience courses in their previous semesters. Hence, they were familiar with general aspects of micro-teaching. After each micro-teaching session, they completed the peer-evaluation form about each other's implementation. In addition, each participant completed a self-evaluation form about his/her own micro-teaching experience.

4.4.3 Data Collection Sources

In case study approach, researchers rely on "multiple sources of evidence" (Yin, 2003, p.14) and theoretical propositions lead selection of these data sources (Yin, 2003). Hence, using several sources of evidences is the strength of case studies (Yin, 2003). In the present study, the data set was gathered before, during, and after the TUME course from multiple sources. All data sources were not used in the data analysis. Data from some of the sources were used to confirm the findings from primary sources. The primary data sources that provided a chain of evidence for TPACK-P proficiency levels to answer the research question of the present study were documentation, observation, and interview. To provide more detail, the list of the data sources and data they provided for the intent of the study from each source were explained in the following three sections referring to before, during, and after the TUME course, respectively.

4.4.3.1 Data Collection Sources Employed Before the TUME Course

Before starting the TUME course, two questionnaires were implemented and a lesson plan assignment was given to the participants to obtain background information in terms of technology familiarity and the ability to integrate technology to lesson design. Table 4.6 presented the data sources before the TUME course.

These two questionnaires were prepared by the researcher to gather information about participants' views about being a competent mathematics teacher and background about technology knowledge. The questionnaires were prepared together by the researcher and a researcher with the doctoral degree in the field of mathematics education who was familiar with the aim of this study. In addition, an educator who had a doctoral degree in Turkish language education also reviewed the questionnaires. The questionnaires were finalized accordingly. They were administered to the participants at the beginning of the semester.

Table 4.6

Data Collection Sources Before the TUME Course

Data Collection Sources	What data were gathered?
Questionnaire 1: The Views about Teaching Profession	Views about technology as part of teacher knowledge and views on the role of technology in education
Questionnaire 2: Technology Usage	Background about computers and other technologies
Lesson Plan 1	Integration of technology to a lesson plan about a middle school mathematics subject

The first questionnaire was The Views about Teaching Profession Questionnaire (see Appendix E). This questionnaire aimed at gaining insights into participants' images of teaching profession. There were two open-ended questions. In the first question, a dialogue between a tailor and his apprentice about being a qualified tailor was given. Analogous to this scenario, participants were asked to mention the knowledge and skills that middle school mathematics teachers should possess and to provide reasons for these. In the second question, participants were asked to give advices to freshmen in order to prepare themselves teaching profession through their four academic years. The second questionnaire was Technology Usage Questionnaire (see Appendix F). This questionnaire consisted of four open-ended questions, as listed below, which aimed to learn about participants' familiarity with computers, the technologies they had encountered before, the technologies they used for their education, the courses they utilized technology, and the reasons of their use.

1. How long have you been using computers?
2. What is your purpose of using computers?
3. In which courses did you use computers?
4. In which courses did you use technology other than computers (calculators, projectors, Smart Boards, etc.)? What were thes technologies? What was the purpose of using them?

Second questionnaire was implemented after all of the participants completed the first one. The reason was not to mention "technology" word, which might have influenced their responses in the first questionnaire. Participants provided answers to both questionnaires approximately in one hour.

Participants were assigned to design a lesson plan in which at least one technology was adapted. They were also required to mention the reason of their choice of the technology and its relation with the content. This data source was aimed at gaining information about participants' TPACK-P level prior to the TUME course.

4.4.3.2 Data Collection Sources Employed During the TUME Course

During the TUME course, there were a number of data sources infused in the context of the course. The data sources, duration of data collection, and the acquisition relevant to each data source was provided in Table 4.7.

Participants were observed through the TUME course for 14 weeks. The observation video records consisted of the implementation of the whole TUME course for a semester and participants' performances throughout the course. As the instructor of the course, the researcher was the participant-observer, which provided the opportunity to investigate and control the events as an insider (Yin, 2003). The purpose of these observations was to investigate participants' performance through the activities, their views about the weekly subjects in classroom discussions, their presentations of activity products, the rationales they provided for their products, and micro-teaching performances. The researcher took field notes during and immediately after the course. These notes were about participants' actions and comments in the course hours referring to their TPACK-P. The individual performances were not always evident in the observation records. Therefore, field notes which mainly included the researcher's immediate written records of participants' individual performances were utilized. The observation data were used to support researcher's field notes.

Table 4.7

Data Collection Sources During the TUME Course

Data Collection Sources	Duration	What data were gathered?
Observation and Researcher's field notes	14 weeks	Information about each participant in the collaborative learning process within group presentations and classroom discussions
Lesson plan 2	To be completed by the 12th week	Which technology, pedagogical methods, and learning goals they chose and how they integrated them
Micro-teaching videos	One video for each participant	How the lesson plan was implemented
Self-assessment of micro-teaching	Last three weeks	Views about the T, P, C, and practical constructs of their own implementation

Participants were assigned to prepare a second lesson plan until the 12th week when the activities were completed. In this assignment, they were challenged to reconsider subject-matter content in the middle school mathematics curriculum which could be taught better and enhance learning when integrated with technology. This assignment was given to identify the level of integration of technology into instruction that matched pedagogical content knowledge with appropriate technological knowledge to enhance teaching and learning. Lesson plan was an important source of evidence for determining participants' TPACK-P development through the 12 weeks of the course, because it provided an opportunity to see their best design of a technology-enhanced mathematics course they intended to teach, by focusing on the technologies they chose and how they adapted technological tools with the appropriate pedagogy to teach a mathematics subject.

Each participant presented the lesson plan to other participants by micro-teaching method. Eleven micro-teaching sessions were video-recorded. This data source provided evidence about participants' practical skills in terms of enacting a technology-enhanced mathematics course. Accordingly, the micro-teaching videos were data sources to identify the consistency between the intended design in the lesson plans and participants' implementation of those lesson plans.

When each micro-teaching was completed, peers evaluated the micro-teaching by filling the peer-assessment form (see Appendix G) and each participant evaluated his/her own micro-teaching by filling the self-assessment form (see Appendix H). These forms were prepared by the researcher. A mathematics education researcher with the doctoral degree who had several studies conducted with qualitative methods and one researcher with doctoral degree in education with experience in qualitative methods reviewed the two questionnaires. The questionnaires were finalized according to their suggestions. Both forms included six open-ended questions asking for the strengths and weaknesses of the micro-teaching, the reasons for considering strengths and the suggestions to remedy the weaknesses, the convenience of the technologies with the pedagogical techniques and content, and required grading the micro-teaching out of 10 points. In addition, there were three boxes for technology, pedagogy, and content. The participants were expected to fill those boxes for what the micro-teaching consisted of. The self-reflection forms were used as a data source to reveal participants' TPACK-P. The peer-reflection forms, on the other hand, were used as an incentive source in the interviews to encourage participants to reflect on their own micro-teaching by seeing others' ideas about their technology-supported course instruction.

4.4.3.3 Data Collection Sources Employed After the TUME Course

Fraenkel and Wallen (2006) stated that interviews contribute to the accuracy of what was observed. Therefore, interviews were conducted as the final data source to interpret all the data obtained from the above mentioned sources. After the TUME course ended, individual interviews were conducted with the participants with the aim of unveiling their perceived TPACK-P development, views on their micro-teaching, and the impact of the TUME course on their professional development as given in Table 4.8.

Table 4.8

Data Collection Sources After the TUME Course

Data Collection Sources	What data was gathered?
Individual interviews	Overall views on the course and on integration of technology in middle school mathematics teaching
	Perceived TPACK-P development throughout the TUME course
	Actual TPACK-P through reflecting on micro-teaching videos and peer- and self- assessment forms

Semi-structured individual interviews were conducted to identify participants' overall views about integrating technology to mathematics education, thereby their TPACK-P development. Their responses were directed by the seven questions and probing sub-questions in the interview protocol which was developed by the researcher based on the TPACK-P framework (see Appendix I). Two educators who had doctorate degree in mathematics education and familiar with technology use in mathematics education and TPACK literature reviewed the questions in terms of content. In addition, two educators who had doctorate degree in Turkish language education inspected the clarity of the questions. Interview questions were finalized according to the views of the four educators. Order of the questions was changed and some questions were combined based on their suggestions. The first interview with one of the participants was conducted as the pilot interview. Throughout this pilot interview, probing questions were added to the protocol. The interview data from this participant was also included in the data set because the probing questions were asked to this participant even though they were not in the original protocol. Each interview was conducted face to face and lasted for an hour in average.

Interview questions aimed to reveal the reasons for participants' decisions of pedagogy and content in their lesson plans, their rationales about how and why they chose to utilize technology, their interpretation of their instruction, the comparison of the micro-teaching with the lesson plan, and the contribution of the course to their teaching profession. In the interview process, in order to gain insight into the process of how they think, design, implement, and reflect on their implementation, they were reminded about their lesson plans, micro-teaching performance, and peer-assessments. They were given the hard-copy of their lesson plans, they watched the parts of their micro-teaching videos, and they were asked to read out loud all of the peer-assessment forms and comment on peers' reflections. Before the question about the contribution of the course to their teaching, the researcher went through the TUME course syllabus and Facebook course page for the participants to recall the content of the course and the activities. Consequently, the content of the questions covered the main components of TPACK-P components. Answers to the interview questions were expected to reveal participants' TPACK-P levels after completing the TUME course.

4.5 Data Analysis

The data sources were documents, observation notes and videos, and interviews. Documents covered the diverse sub-sources which were pre-questionnaires, initial and final lesson plans, and self-assessment forms. Observation data source covered participants' progress in the TUME course and discussions as expressed in researcher's field notes and video records of their micro-teaching performances. Interviews covered participants' statements about all of their experiences within the TUME course and their views on the peer and self-reflection forms. The data from these sources altogether aimed at revealing the participants' TPACK-P development through the TUME course. Content analysis technique was employed to analyze the data. Triangulation of multiple sources should be considered to maximize evidence in qualitative studies and to reveal converging themes of the phenomena (Yin, 2003). In this study, convergence of multiple sources of evidence (Yin, 2003) was maintained in data analysis.

Relying on a framework was suggested by Yin (2003) as one of the analytical strategies in data analysis. The data analysis relied on TPACK-P framework. Propositions in the TPACK literature and TPACK-P framework led the design of the TUME course, data sources, and the analysis of the data. The aim and the data collection procedure of the present study were introduced via e-mail to the researchers who proposed the TPACK-P framework (Yeh, Hsu, Wu, et al., 2014) and the ensuing studies related with it. Their suggestions confirmed drawing out specific indicators from their explanations to the four levels in their framework. Therefore, first, the existing indicators belonging to TPACK-P levels were divided into pieces in order to obtain single skill, action, or thought in each indicator. Then, the word *science* was replaced with the word *mathematics*. Because the TPACK-P framework was the product of the research which was specifically on science content and the word *science* was used in the benchmarks and indicators of the TPACK-P levels in the framework.

In order to determine whether it was necessary to include more descriptive behaviors of TPACK-P to make the rubric to analyze data obtained from PMTs more comprehensively, the researcher read all of the documents and transcribed data and watched the observation and micro-teaching videos. The researcher selected three participants' data randomly and asked a mathematics education researcher with a doctoral degree about mathematics teachers' TPACK development to match the behaviors and knowledge of the participants with the existing indicators in the rubric.

The researcher and the mathematics educator went through three participants' lesson plans, micro-teaching videos, and interview transcriptions together diffusively to see if any new indicator was needed to be added to the rubric. There were no additional behaviors or thoughts appeared in the data.

Therefore, TPACK-P indicators were not expanded or synchronized. Besides, there were no marginal skills, actions, or thoughts emerged that did not suit the content of the rubric. Hence, the rubric in Table 4.9 was comprehensive, thereby efficient to analyze all the data to evaluate participants' TPACK-P. In addition to the indicators, exemplary behaviors and knowledge for each indicator of the TPACK-P levels were also written on the rubric to describe and embody the indicators. These behaviors and knowledge were presented by Jen et al. (2016) in their 17-item questionnaire. They were written under the related indicator in italic format. The rubric consisted of criteria about expected behaviors and knowledge belonging to each TPACK-P level within the three domains of 1) assessment, 2) planning and design, and 3) enactment. The benchmarks, indicators, and exemplary behaviors and knowledge were presented separately in the rubric in Table 4.9.

In order to understand whether the prepared rubric was a useful data analysis tool for the data, a pilot study for the use of the rubric was conducted. A researcher who was about to complete her doctoral study about mathematics teachers' TPACK development analyzed two participants' lesson plans, micro-teaching videos, and interview transcripts via using the rubric for inter-rater reliability. Two participants' data were selected due to providing the longest and shortest data and assumed to be the most and least detailed data, respectively. The data from each participant's second lesson plan, micro-teaching video, and interview transcript were considered while using the rubric. The separately coded data analysis results for two participants were cross-referenced between two inter-raters. When the discrepancies were compared, there were three different selections for one of the participants and one for the other participant. The different indicators showed difference in consecutive levels. In other words, the researcher selected one indicator from level 2 and the other rater selected an indicator from level 3 for the same behavior in enactment domain. However, the overall level of the participant with respect to the enactment domain remained the same in both ratings. This indicated that there was a considerable consistency between the two inter-raters and the rubric was useful for analyzing the data collected throughout the study.

Table 4.9

TPACK-P Rubric

TPACK-P Assessment Domain			
Level 4 – Reflective application	Level 3 – Infusive application	Level 2 – Simple adoption	Level 1 – Lack of use
Benchmark: Evaluate students' learning of and about mathematics before and after mathematics learning.	Benchmark: Use technology to assess students before and after instruction.	Benchmark: Evaluate students through presenting content with ICTs.	Benchmark: Think technology make no specific contributions to student evaluation.
Observed indicators: 1. Be able to use various representations or ICTs in instruction that enables teachers to identify students' learning styles and learning difficulties (e.g., cognitive, affective) for the preparation of adaptive instruction. *Use of videos/animation in the classroom helps me elicit students' prior knowledge and/or misconceptions.*	Observed indicators: 1. Be able to use appropriate technology or online platforms to observe students' learning styles and learning difficulties and to assist student learning. *Use of videos/animation help me assess students' content comprehension through dynamic presentations.* *Simulations help me to observe the difficulties students face from their simulation manipulations.*	Observed indicators: 1. Be able to use different representations or ICTs to present mathematics content, from which they observe students' learning performance and student learning is made possible. *Use of videos/animation helps me learn how students feel about the use of videos /animation in instruction.*	Observed indicators: 1. Think technology are not good tools to be used for knowing students' learning styles or learning difficulties. *I don't believe videos /animation are useful for assessing students' individual differences.* *I don't believe simulations to be good tools for use in identifying students' learning difficulties.*

Table 4.9

TPACK-P Rubric (continued)

TPACK-P Assessment Domain			
Level 4 – Reflective application	Level 3 – Infusive application	Level 2 – Simple adoption	Level 1 – Lack of use
I can identify students' learning difficulties when they use simulations to learn mathematics personally or collaboratively. *Teachers can use technology integration to adaptively assess students' knowledge, and then offer instruction based on that assessment.* 2. Be able to construct technology-supported assessments through which students' knowledge of and about mathematics can be evaluated.	*Technology integration can present difficult subject content in diverse and efficient ways for students to understand.* 2. Be able to implement appropriate multimedia or ICT tools into instruction for the purposes of evaluation and learning. *Multimedia assessments allow for evaluations of various aspects of learning in ways that exceed limited conventional assessments.*	*Simulations help me to discover students' learning difficulties when I use them to demonstrate phenomena, and then ask follow-up questions.* *Technology integration allows students with different motivations or learning backgrounds to be independent learners.* 2. Be able to use online assessments, digital representation or ICT tools to evaluate students' learning.	*I don't believe that technology integration in class to assist students with different learning styles/needs.* 2. Think technology-supported assessments are no different from conventional assessments 3. They have concerns regarding implementing ICTs to assist their assessments. *For 2 and 3:* *Conventional assessments are more efficient than technology-supported assessments in terms of student evaluation.*

Table 4.9

TPACK-P Rubric (continued)

TPACK-P Assessment Domain			
Level 4 – Reflective application	Level 3 – Infusive application	Level 2 – Simple adoption	Level 1 – Lack of use
Teachers can construct items that have multiple representations to be used for different evaluation purposes. *Technology-supported assessments allow students to manipulate simulations and present their thinking processes.* *To evaluate students in mathematics instruction, teachers can present mathematical phenomena in diverse ways, which implies student learning can be evaluated from a wide range of perspectives.*	*Technology-supported assessments, as compared to conventional assessments present dynamic content through multimedia.* *Teachers can use online platforms to offer students summative assessments or repeated practices; students' learning progress can also be recorded.*	*Test bank CD-ROMs offer efficient technology-supported assessments.* *Technology-supported assessments, as compared to conventional assessments offer instant feedback and preliminary score analyses.* *Teachers can ask students to complete mathematics projects with technology and use their project as summative assessments of their learning.*	*Between technology-supported assessments and conventional assessments, there are no major differences in terms of item content; the key difference is in the interfaces they use to present information.* *Technology-supported assessments are not appropriate for implementation in instruction.*

Table 4.9

TPACK-P Rubric (continued)

TPACK-P Planning and Design Domain			
Level 4 – Reflective application	Level 3 – Infusive application	Level 2 – Simple adoption	Level 1 – Lack of use
Benchmark: Design technology-supported instruction that accommodates students' learning of and about mathematics.	Benchmark: Design technology-supported instruction from the student-centered perspective or with a focus on developing students' mathematics learning.	Benchmark: Design technology-supported instruction with a focus on developing students' content comprehension or learning motivation.	Benchmark: Think technology make no specific contributions to curriculum design over conventional teaching.
Observed indicators: 1. Be able to utilize functions of technology to facilitate teachers' (their) exploration of mathematical phenomena and construction of their mathematics knowledge. 2. Be able to utilize functions of technology to facilitate students' exploration of mathematical phenomena and construction of their mathematics knowledge.	Observed indicators: 1. Be able to use appropriate representations or ICT tools to facilitate teachers' (their) mathematics learning through investigating and mathematical phenomena and making virtual experiments.	Observed indicators: 1. Be able to use representations or ICT tools for teachers (themselves) to learn abstract concepts. 2. Be able to use representations or ICT tools for students to learn abstract concepts.	Observed indicators: 1. View learning mathematics content through technology no better than learning from professional books or magazines. *Consulting professional books and magazines is a better way of acquiring content knowledge for teachers.*

Table 4.9

TPACK-P Rubric (continued)

TPACK-P Planning and Design Domain			
Level 4 – Reflective application	Level 3 – Infusive application	Level 2 – Simple adoption	Level 1 – Lack of use
For 1 and 2: *Teachers can learn more abstract concepts by using different technology functions (ex: multiple representations, slow motion displays).* *Concepts that need students to learn from manipulating simulations or doing experiments are suited to teaching with technology-supported instruction.* 3. Consider and design technology-supported curricula for the purpose of enhancing students' learning of and about mathematics with skillful use of technology.	2. Be able to use appropriate representations or ICT tools to facilitate students' mathematics learning through investigating and mathematical phenomena and making virtual experiments. *For 1 and 2:* *Teachers can reference verified sources that professional websites offer (ex: research institute websites).* *Abstract concepts that are difficult to present in conventional instruction are suited to teaching with technology-supported instruction.* 3. Consider and design technology-supported instruction for enhancing instructional effectiveness and students' learning of mathematics.	*For 1 and 2:* *Teachers can keep up to date from attending workshops or use online resources shared by internet-based teaching community.* *Units that require students' motivation to learn are suited to teaching with technology-supported instruction.* 3. Consider technology uses in instruction according to external factors. 4. Consider technology uses in instruction according students' learning motivations.	*I don't believe that there is a significant difference between technology-supported and conventional instruction when it comes to subject content presentation.* 2. Consider teaching with technology to be an alternative instructional method to conventional instruction. *The amount of time spent in curriculum preparation (which may decrease teachers' willingness to teach with technology) can influence teachers' planning and designing of their technology-supported instruction.*

Table 4.9

TPACK-P Rubric (continued)

TPACK-P Planning and Design Domain			
Level 4 – Reflective application	Level 3 – Infusive application	Level 2 – Simple adoption	Level 1 – Lack of use
The increased efficiency of teacher instruction can influence teachers' planning and designing of their technology-supported instruction. *To enhance instructional efficiency and improve students' comprehension and thinking abilities are the instructional objectives which are appropriate for technology-supported instruction.* 4. Be able to construct technology-supported curricula based on students' prior knowledge or for purposes of inquiry learning, with strategic uses of digital representations or ICT tools.	*The improved visual effects of graphic designs and concept presentations can influence teachers' planning and designing of their technology-supported instruction.* *To help students form a better understanding of the course content and clarify key concepts are the instructional objectives which are appropriate for technology-supported instruction.* 4. Be able to implement appropriate digital representations or ICT tools that facilitate students' learning of abstract concepts and mathematical investigations.	*For 3 and 4:* *The enhancement of student learning motivations and responses can influence teachers' planning and designing of their technology-supported instruction.* *To improve students' learning motivation are the instructional objectives which are appropriate for technology-supported instruction.* 5. Be able to present mathematics content with digital representations that are available and good for enhancing students' learning motivations.	*No special objectives need to be set for technology-supported instruction (To achieve the objectives like those teachers set for their conventional instruction).* 3. Consider technology to be useful only in limited instructional occasions. *Presenting textbook content in PPT satisfies my instructional needs.* 4. View teaching with technology to be good enough for instructional purposes, in need of no other teaching strategies for support.

Table 4.9

TPACK-P Rubric (continued)

TPACK-P Planning and Design Domain			
Level 4 – Reflective application	Level 3 – Infusive application	Level 2 – Simple adoption	Level 1 – Lack of use
Selection the appropriate technology tools for content presentation is based on students' prior knowledge, instructional procedures, and subject concepts.	*Selection the appropriate technology tools for content presentation depends upon how explicit technology present subject content and how helpful they guide students to think mathematically.*	*Selection the appropriate technology tools for content presentation depends upon the availability of resources (ex: animation, images, PowerPoint).*	*Teaching with technology already accommodates my instructional needs; no other instructional strategies are required.*
5. Be able to use student-centered instructional strategies to accommodate students' learning of and about mathematics inquiry-based tasks in technology-supported environment.	5. Be able to use appropriate instructional strategies to facilitate teachers' instruction and student learning of mathematics in technology-supported curricula (e.g. engaging students in collaborative learning).	6. Be able to teach mathematics with technology in couple of instructional strategies for the purpose of enhancing students' motivations and conceptual understanding.	*Group collaboration does not offer anything special to technology-supported instruction.*
For the teaching strategies to assist technology-supported instruction, I guide students to use technology tools or learn with inquiry for their self-learning.	*For the teaching strategies to assist technology-supported instruction, I engage students in group collaboration to promote their comprehension.*	*For the teaching strategies to assist technology-supported instruction, I use a questioning strategy or ask students to draw from their impressions to help them identify key concepts.*	

Table 4.9

TPACK-P Rubric (continued)

TPACK-P Planning and Design Domain			
Level 4 – Reflective application	Level 3 – Infusive application	Level 2 – Simple adoption	Level 1 – Lack of use
A technology-supported environment that accommodates students' collaborative completion of tasks can be developed, but personal learning outcomes should also be carefully considered.	*Technology can present course content for groups to discuss and present group findings/learning to the class when group collaborations are coupled with technology-supported instruction.*	*Students can develop a more positive attitude toward learning (ex: participation, learning motivation, concentration) when group collaborations are coupled with technology-supported instruction.*	
TPACK-P Enactment Domain			
Benchmark:	Benchmark:	Benchmark:	Benchmark:
Use technology skillfully to assist instructional material creation and student independent learning.	Use technology flexibly to assist students' learning and teachers' instruction management.	Use technology to make teaching more interesting and better supported.	Think technology make no contributions to teaching practices.
Observed indicators:	Observed indicators:	Observed indicators:	Observed indicators:
1. Be able to use a variety of technology flexibly and strategically to accommodate students' different learning needs.	1. Be able to use appropriate technology to improve the quality of content presentation.	1. Be able to implement technology in class to impress students in mathematics learning.	1. Believe teaching with technology brings similar contributions to student learning as conventional instruction.

Table 4.9

TPACK-P Rubric (continued)

TPACK-P Enactment Domain			
Level 4 – Reflective application	Level 3 – Infusive application	Level 2 – Simple adoption	Level 1 – Lack of use
2. Be able to use a variety of technology flexibly and strategically to support students' knowledge construction. 3. Be able to use a variety of technology flexibly and strategically to improve instructional effectiveness. *For 1,2, and 3:* *Technology-supported instruction helps abstract concepts and related examples to be concretely visualized in less time.* *Synchronous communication tools offer diverse learning opportunities and assessment methods.*	2. Be able to use appropriate technology to support communications. 3. Be able to use appropriate technology to build up students' learning profiles. *For 1,2, and 3* *Technology-supported instruction allows concepts to be presented more explicitly than teachers' visual or oral explanations.* *Synchronous communication tools improve teacher-student interactions in non-classroom settings.* *I upload learning materials online for student learning.*	2. Be able to implement technology in class make teachers' instruction easier. *For 1 and 2:* *Technology-supported instruction leaves students excited and makes a lasting impression.* *Synchronous communication tools benefit students who are active in learning.* *I meet with students beyond class hours.* 3. Be able to use word processors or online platforms to manage instructional resources.	*I don't believe that there is a difference in student learning between technology-supported instruction and conventional instruction.* *Teachers are less willing to use synchronous communication tools in instruction due to the high demands of technology.* *I use chalk-and-talk instruction instead (I use none of the above).* 2. View current technology as not accommodating teachers' needs in instructional management.

Table 4.9

TPACK-P Rubric (continued)

TPACK-P Enactment Domain			
Level 4 – Reflective application	Level 3 – Infusive application	Level 2 – Simple adoption	Level 1 – Lack of use
I use previously prepared teaching materials (ex: online or standalone versions). 4. Be able to customize instructional materials with skillful uses of technology or multimedia resources for different instructional purposes. *Curricula can become innovative and cross-disciplinary, when digital educational resources are meaningfully and purposefully integrated.*	*I upload learning materials online for student learning.* 4. Be able to use different technology to manage instructional resources. 5. Be able to use different technology to track student learning progress. *For 4 and 5:* *Online platforms can be useful for profiling students' collaborative learning progress and learning outcomes.*	*Operating systems (e.g., Microsoft) can be useful when organizing teaching materials that have been collected over a long period of time.*	*Current technology cannot effectively improve teachers' instructional management.*

Note. Adapted from "Science Teachers' TPACK-Practical: Standard-Setting Using an Evidence-Based Approach," by T. H. Jen, Y. F. Yeh, Y. S. Hsu, H. K. Wu, and K. M. Chen, 2016,*Computers & Education*, *95*, p. 49.

In the data analysis, firstly, it was aimed to determine each participant's TPACK-P levels for three pedagogical domains. The knowledge and behaviors of each participant gathered from the data sources were placed under the related indicators existed in the TPACK-P rubric. The benchmarks, indicators, and sample behaviors existed in the rubric were helpful for deciding where to place the participant's knowledge and behaviors. Some examples were provided below to explain how the knowledge and behaviors of participants were aligned with the indicators in the rubric. The data analysis was explained by providing instances of PMTs' knowledge and behaviors gathered from various data sources. These examples regarding assessment domain, planning and design domain, and enactment domain were presented in Tables 4.10, 4.11, and 4.12, respectively.

Table 4.10

TPACK-P Rubric for Assessment Domain

TPACK-P Levels	Benchmarks, Indicators, and Example Behaviors
Level 4 – Reflective application	Benchmark: Evaluate students' learning of and about mathematics before and after mathematics learning.
	Observed indicators and related knowledge and behaviors: 1. Be able to use various representations or ICTs in instruction that enables teachers to identify students' learning styles and learning difficulties (e.g., cognitive, affective) for the preparation of adaptive instruction. P11 conducted an activity on GeoGebra. (Lesson plan and micro-teaching video) P11 addressed questions to the class continuously to identify students' prior knowledge about the properties of a parallelogram. (Micro-teaching video) *"I managed the instruction according to the students' answers reflecting what they know about the content."* (P11, Interview) 2. Be able to construct technology-supported assessments through which students' knowledge of and about mathematics can be evaluated. P11 implemented a quiz on the online assessment platform Socrative. (Lesson plan and micro-teaching video) P11 provided feedback to the students based on the performance report provided by the online assessment platform. (Micro-teaching video) *"I conducted a quiz on Socrative both to assess mathematical knowledge and to evaluate my instruction."* (P11, Interview)

Table 4.10

TPACK-P Rubric for Assessment Domain (continued)

TPACK-P Levels	Benchmarks, Indicators, and Example Behaviors
Level 3 – Infusive application	Benchmark: Use technology to assess students before and after instruction.
	Observed indicators and related knowledge and behaviors: 1. Be able to use appropriate technology or online platforms to observe students' learning styles and learning difficulties and to assist student learning. P3 conducted an origami activity in the beginning of the instruction by utilizing a demonstrative video from YouTube. (Lesson plan and micro-teaching video) *"I demonstrated the video to assist students visually."* (P3, Interview) *"Videos provide visual support and provide all students to engage in the activity."* (P3, Self-assessment form) 2. Be able to implement appropriate multimedia or ICT tools into instruction for the purposes of evaluation and learning. P3 directed questions about basic properties of triangles and rectangles through the activity referring to the steps on the video. (Lesson plan and micro-teaching video)
Level 2 – Simple adoption	Benchmark: Evaluate students through presenting content with ICTs.
	Observed indicators and related knowledge and behaviors: 1. Be able to use different representations or ICTs to present mathematics content, from which they observe students' learning performance and student learning is made possible. P10 used the online assessment program Socrative at the end of the course. (Lesson plan and micro-teaching video) *"As a teacher it is easy to prepare quizzes either premeditated or instantly-decided through utilizing different types of question formats."* (P10, Interview) 2. Be able to use online assessments, digital representation or ICT tools to evaluate students' learning. *"I used Socrative to increase participation. It is useful to engage students with different backgrounds and motivations to the assessment process."* (P10, Interview)
Level 1 – Lack of use	Benchmark: Think technology make no specific contributions to student evaluation.
	Observed indicators and related knowledge and behaviors: 1. Think technology are not good tools to be used for knowing students' learning styles or learning difficulties. 2. Think technology-supported assessments are no different from conventional assessments or they have concerns regarding implementing ICTs to assist their assessments. 3. They have concerns regarding implementing ICTs to assist their assessments.

In the assessment domain, a teacher in level 2 is expected to "be able to use different representations or ICTs to present content, from which they observe students' learning performance […] and to evaluate students' learning" (Jen et al., 2016, p. 49). For instance, P10 expressed in the interview that she took advantage of online assessment programs to enhance participation of students with different backgrounds and motivations. She also mentioned in the interview that *"as a teacher it is easy to prepare quizzes either premeditated or instantly-decided through utilizing different types of question formats."* However, she did not consider the students' performance on the performance report that the online assessment programs provided and did not use the results to discuss about wrong answers. Therefore, she was considered to be at level 2 in Assessment domain. On the other hand, P3 conducted an origami activity in the beginning of the instruction by supporting the activity with a demonstrative video from YouTube. P3 implied in the interview that she utilized the video to assist students by providing visual representation of the activity. Moreover, she directed questions about basic properties of triangles and rectangles through the activity. In these knowledge and behaviors, technology was not directly utilized for assessing students' prior knowledge and needs. Rather, it was selected and used to assist student understanding. This was aligned with the first indicator of level 3 in Assessment domain that the teacher is "able to implement appropriate multimedia or ICT tools into instruction for the purposes of evaluation and learning" (Jen et al., 2016, p. 49). In the end of the course, P3 utilized the online assessment platform Socrative same as P11. However, P3 did not provide feedback for open-ended questions in the quiz. She aimed at assessing students' mathematics knowledge. Therefore, P3 was determined to be at level 3 in Assessment domain. The indicators in level 3 state that the teacher is "able to use appropriate technology or online platforms to observe students' learning styles and learning difficulties and to assist student learning" (Jen et al., 2016, p. 49). In the assessment domain, the highest level of TPACK-P anticipates teachers to assess and evaluate students in terms of their mathematics knowledge both before and after the instruction through utilizing various representations provided by appropriate technologies. In addition to assessing mathematics knowledge, students' learning needs and styles should be identified to design and implement effective instructions. For instance, P11 initiated her micro-teaching with an activity on GeoGebra. She addressed questions to the class continuously to identify students' prior knowledge about the properties of a parallelogram. She expressed in the interview that she managed the rest of the instruction according to the students' prior knowledge. At the end of her micro-teaching P11 implemented a quiz that she had prepared before the course on the online assessment platform Socrative. She provided feedback to the students based on the performance report provided by the online assessment platform. The online program showed the false and true answers after every question. She guided classroom discussions to criticize false answers. P11 implied in the interview that she used Socrative in post-assessment both to assess students' mathematical knowledge and for evaluation of her teaching. In the assessment domain, the highest level of TPACK-P anticipates teachers to assess and evaluate students in terms of their mathematics knowledge both before and after the instruction through utilizing various representations provided by appropriate technologies. In addition to assessing mathematics knowledge, students' learning needs and styles should be identified to design and implement effective instructions. Therefore, P11 was determined to be at level 4 in Assessment domain. TPACK-P rubric for Planning and Design Domain with example behaviors are given in Table 4.11 below.

In Planning and Design domain, the benchmarks explain what is expected from the teacher in each level (Table 4.11). It was stated in the benchmark of level 2 that teachers design technology-infused instructions "with a focus on developing students' content comprehension or learning motivation" (Jen et al., 2016, p. 49). The plans that consisted teacher-centered use of technology and aiming only motivation and comprehension of the content were aligned with level 2. For instance, P7 planned to use calculators in calculation-based estimation topic belonging to the 5th grade.

Table 4.11

TPACK-P Rubric for Planning and Design Domain

TPACK-P Levels	Benchmarks, Indicators, and Example Behaviors
Level 4 – Reflective application	Benchmark: Design technology-supported instruction that accommodates students' learning of and about mathematics.
	Observed indicators and related knowledge and behaviors: 1. Be able to utilize functions of technology to facilitate teachers' (their) exploration of mathematical phenomena and construction of their mathematics knowledge. 2. Be able to utilize functions of technology to facilitate students' exploration of mathematical phenomena and construction of their mathematics knowledge. P1 planned to utilize GeoGebra to demonstrate the relationship between height and base in three types of triangles. (Lesson plan) P1 planned to use GeoGebra for providing exploration, rationalization, and association of concepts. (Interview) *"GeoGebra served to build connection between concepts of height, angle, base, and area of a triangle."* (P1, Interview) 3. Consider and design technology-supported curricula for the purpose of enhancing students' learning of and about mathematics with skillful use of technology. 4. Be able to construct technology-supported curricula based on students' prior knowledge or for purposes of inquiry learning, with strategic uses of digital representations or ICT tools. The activity aimed to overcome two misconceptions. (Lesson plan) *"GeoGebra provided the necessary representations and dynamicity to overcome the two misconceptions."* (P1, Self-assessment form and interview) 5. Be able to use student-centered instructional strategies to accommodate students' learning of and about mathematics inquiry-based tasks in technology-supported environment. P1 designed a student-centered activity on GeoGebra. (Lesson plan and interview)
Level 3 – Infusive application	Benchmark: Design technology-supported instruction from the student-centered perspective or with a focus on developing students' mathematics learning.
	Observed indicators and related knowledge and behaviors: 1. Be able to use appropriate representations or ICT tools to facilitate teachers' (their) mathematics learning through investigating mathematical phenomena and making virtual experiments. 2. Be able to use appropriate representations or ICT tools to facilitate students' mathematics learning through investigating mathematical phenomena and making virtual experiments. P8 planned to use isometric background on Smart Board to explicitly present content, promote mathematical thinking, and provide students the opportunity to construct their own knowledge. (Lesson plan and interview)

Table 4.11

TPACK-P Rubric for Planning and Design Domain (continued)

Level 3 – Infusive application	3. Consider and design technology-supported instruction for enhancing instructional effectiveness and students' learning of mathematics. 4. Be able to implement appropriate digital representations or ICT tools that facilitate students' learning of abstract concepts and mathematical investigations. 5. Be able to use appropriate instructional strategies to facilitate teachers' instruction and student learning of mathematics in technology-supported curricula (e.g. engaging students in collaborative learning). P8 planned to guide students to work collaboratively while working on isometric background to reach the general rule for perimeter and area. (Lesson plan and interview)
Level 2 – Simple adoption	Benchmark: Design technology-supported instruction with a focus on developing students' content comprehension or learning motivation.
	Observed indicators and related knowledge and behaviors: 1. Be able to use representations or ICT tools for teachers (themselves) to learn abstract concepts. 2. Be able to use representations or ICT tools for students to learn abstract concepts. 3. Consider technology uses in instruction according to external factors. 4. Consider technology uses in instruction according to students' learning motivations. 5. Be able to present mathematics content with digital representations that are available and good for enhancing students' learning motivations. P7 planned to use calculators in calculation-based estimation topic belonging to the 5th grade. (Lesson plan) The teacher uses the calculator to show the actual results of the calculations. (Lesson plan) "My aim was to motivate learners to make more accurate guesses." (P7, Interview) 6. Be able to teach mathematics with technology in couple of instructional strategies for the purpose of enhancing students' motivations and conceptual understanding.
Level 1 – Lack of use	Benchmark: Think technology make no specific contributions to curriculum design over conventional teaching.
	Observed indicators and related knowledge and behaviors: 1. View learning mathematics content through technology no better than learning from professional books or magazines. 2. Consider teaching with technology to be an alternative instructional method to conventional instruction. 3. Consider technology to be useful only in limited instructional occasions. 4. View teaching with technology to be good enough for instructional purposes, in need of no other teaching strategies for support.

P7 planned that the teacher uses the calculator to express the actual results of the calculations to motivate learners to make more accurate guesses. Whereas, in level 3, the instruction is designed "from the student-centered perspective or with a focus on developing students' learning" (Jen et al., 2016, p. 49). For instance, P8 planned to use Smart Board technology to explicitly present content, promote mathematical thinking, and provide students the opportunity to construct their own knowledge. P8 planned to use isometric background on Smart Board by guiding students to reach the perimeter and area formula of a square. To achieve this, she planned to guide students to draw squares with different sizes on the Smart Board, calculate the perimeter and area for each of them by making use of isometric background, and then interpret the general rule for perimeter and area collaboratively by brainstorming technique. In level 4, in addition to the student-centered design of the technology-infused instruction, the instruction is designed in a way that "accommodates students' learning of and about" (Jen et al., 2016, p. 49) the content. For instance, P1 utilized GeoGebra to demonstrate the relationship between height and base in three types of triangles. In her lesson plan, she designed a student-centered activity on GeoGebra aiming to overcome two misconceptions regarding this subject. She explained in the interview and self-assessment form that this was available by the representations and dynamicity that GeoGebra provided. Moreover, she referred to the role of GeoGebra for exploring and rationalizing mathematics and associating concepts. She stated that GeoGebra served to build connection between concepts of height, angle, base, and area of a triangle. P1 was "able to utilize functions of technology to facilitate students' exploration of mathematical phenomena and construction of their mathematics knowledge" as indicated in level 4 in Planning and Design domain. In addition, P1 considered the most common misconceptions and was "able to construct technology-supported curricula […] for purposes of inquiry learning, with strategic uses of digital representations or ICT tools" (Jen et al., 2016, p. 49). Therefore, P1's lesson design was aligned with level 4 in Planning and Design domain. Table 4.12 below illustrates TPACK-P rubric for Enactment Domain with example behaviors.

Table 4.12

TPACK-P Rubric for Enactment Domain

TPACK-P Levels	Benchmarks, Indicators, and Example Behaviors
Level 4 – Reflective application	Benchmark: Use technology skillfully to assist instructional material creation and student independent learning.
	Observed indicators and related knowledge and behaviors: 1. Be able to use a variety of technology flexibly and strategically to accommodate students' different learning needs. 2. Be able to use a variety of technology flexibly and strategically to support students' knowledge construction. She utilized GeoGebra to make students learn through constructing a parallelogram. (Micro-teaching video) 3. Be able to use a variety of technology flexibly and strategically to improve instructional effectiveness. P11 implemented about the parallelogram which covered three objectives from the 7th grade and one objective from the 8th grade. (Lesson plan and micro-teaching video) 4. Be able to customize instructional materials with skillful uses of technology or multimedia resources for different instructional purposes. P11 implemented the activity in a student-centered environment by using question and answer technique to incorporate students in the construction activity. (Micro-teaching video)
Level 3 – Infusive application	Benchmark: Use technology flexibly to assist students' learning and teachers' instruction management.
	Observed indicators and related knowledge and behaviors: 1. Be able to use appropriate technology to improve the quality of content presentation. P5 implemented an origami activity to construct a cube to teach addition of fractions with equal and unequal denominators in the 5th grade level. She featured an origami video from YouTube online video channel at the time of the activity. (Micro-teaching video) 2. Be able to use appropriate technology to support communications. P5 guided students to work collaboratively and facilitate from the video together in groups. (Micro-teaching video) P5 guided a discussion environment based on the video. (Micro-teaching video) P5 expressed that she utilized demonstration on video to manage and improve the quality of the instruction. (Interview) 3. Be able to use appropriate technology to build up students' learning profiles. Students worked collaboratively through the technology-supported activity. 4. Be able to use different technology to manage instructional resources. 5. Be able to use different technology to track student learning progress.

Table 4.12

TPACK-P Rubric for Enactment Domain (continued)

TPACK-P Levels	Benchmarks, Indicators, and Example Behaviors
Level 2 – Simple adoption	Benchmark: Use technology to make teaching more interesting and better supported.
	Observed indicators and related knowledge and behaviors: 1. Be able to implement technology in class to impress students in mathematics learning. P3 presented a cube-construction video from YouTube video sharing channel. (Micro-teaching video) P3 aimed at enhancing active participation by motivating students with the visual demonstration. (Self-assessment form and interview) 2. Be able to implement technology in class to make teachers' instruction easier. P3 expressed that she utilized the video to support mathematical investigation visually and to make instruction easier. (Interview) 3. Be able to use word processors or online platforms to manage instructional resources.
Level 1 – Lack of use	Benchmark: Think technology make no contributions to teaching practices.
	Observed indicators and related knowledge and behaviors: 1. Believe teaching with technology brings similar contributions to student learning as conventional instruction. 2. View current technology as not accommodating teachers' needs in instructional management.

In Enactment domain, level 2 indicates that a teacher implements technology "to impress students" and "to make teachers' instruction easier" (Jen et al., 2016, p. 50). For instance, P3 used a cube-construction video from YouTube video sharing channel to support students' mathematical investigation by the demonstration of the origami activity and to support her instruction visually. She expressed in the interview that her aim was to enhance active participation by impressing students. Therefore, her performance was aligned with level 2. Similarly, P5 implemented an origami activity to construct a cube where she managed students to work in groups. Meanwhile, P5 featured a video from YouTube online video channel at the time of the activity. The video was demonstrating the steps of the origami activity. The subject was addition of fractions with equal and unequal denominators in the 5th grade level. She guided a discussion which proceeded based on the content of the video. P5's application was superior than the application of P3 in several pedagogical aspects. This was a student-centered construction activity including multiple representations that were conducted in a collaborative environment in which P5 utilized technology to manage and improve the quality of the instruction. The benchmark and indicators in level 3 identify that teachers “use technology flexibly to assist students’ learning and teachers’ instruction management”, “to improve the quality of content presentation”, and “to support communications” (Jen et al., 2016, p. 49). Therefore, P5’s implementation was aligned with level 3 in Enactment domain. In level 4, teachers are expected to use technology skillfully, flexibly, and strategically “to accommodate students’ different learning needs”, “to support students’ knowledge construction”, and “to improve instructional effectiveness” (Jen et al., 2016, p. 49). P11 designed a plan about the parallelogram which covered three objectives from the 7th grade and one objective from the 8th grade. P11 was “able to customize instructional materials with skillful uses of technology […] for different instructional purposes” (Jen et al., 2016, p. 49). She utilized GeoGebra in teaching the first three objectives through construction of a parallelogram collaboratively with students. P11 implemented the activity in a student-centered environment by using question and answer technique to incorporate students in the construction activity. Therefore, she was determined at level 4 in Enactment domain.

The researcher analyzed the data of all participants separately. The first step of the analysis was resulted with eleven rubrics belonging to each participant. Then, for each participant, the data from all sources were triangulated to support her/ his emerging level that appeared in the analysis based on the rubric. This provided a better understanding and nature of each participant’s TPACK-P development through the TUME course. After evaluating each participant separately, eleven filled-out rubrics were superimposed to see the evaluation of eleven participants all together. The TPACK-P rubrics for eleven participants showed that a participant having a high level in a domain can be at a lower level in other domains. Participants were clustered according to the interpretive results of their TPACK-P levels. The rule applied for forming groups was that if a participant progressed at a level in at least two domains then the participant was considered to be at that level for overall TPACK-P. To illustrate, P3 performed at level 3 in Assessment domain and Planning and Design domain and performed at level 2 in Enactment domain. P3 was accepted to be in level 2 in her overall TPACK-P performance due to progressing at level 3 in two domains. The groups were formed likewise. It was not appropriate to identify a participant to be at a level although he did not perform at that level in one domain. Therefore, the names of the groups were formed by modifying the names of the levels. Consequently, the names of the groups were determined as Mostly Simple Adoption group, Mostly Infusive Application group, and Mostly Reflective Application group.

In carrying out the analyses of multiple sources, the aim was to strengthen the research findings and enhance better understanding of the PMTs' TPACK-P development. Horizontal analysis of all data belonging to each participant provided determination of TPACK-P levels for each participant. The overall analysis was conducted from a holistic perspective (Patton, 2002) which aimed at determining eleven participants' overall progress in terms of TPACK-P competencies throughout the TUME course.

4.6 Trustworthiness of the Study

In this study, single case study approach was employed. Therefore, the validity and reliability issues were explained based on qualitative research principles referring as the trustworthiness of the study (Merriam, 2009). The possible threats to trustworthiness and precautions taken to overcome these threats were explained in this section. Researchers need to conduct multiple strategies for validation to demonstrate the accuracy of the results (Creswell, 2013). The strategies to display the preciseness of the findings were identified in this section.

Credibility is the first issue to be considered as it is related with the data collection process. Yin (2003) indicated that the researcher should state what specific issue he intends to investigate and decide what measures provide evidences for the research problem. The strategies employed in this research were using multiple data sources to provide saturated evidence and find converging patterns among the data gathered from multiple sources. In this research, trustworthiness was attained by data triangulation as the case was explored by multiple sources of evidence to increase the accuracy, authenticity, and trustworthiness of the results (Patton, 1999).

The researcher was the key instrument as being both the instructor of the TUME course and the first-hand data collector in all steps of the study. The influence of being involved in all parts of the study might have affected the data analysis, and therefore the results of the study. Data triangulation remedied researcher bias (Patton, 1999) that would have been aroused from researcher's participant observer role and from being the instructor of the course. In addition, to remedy this effect, peer-coding technique were used in the analyses.

The two strategies which were triangulation of data obtained from multiple sources and peer-coding promoted to obtain confirmability. First of all, triangulation provided to maintain a chain of evidence (Yin, 2003). Secondly, there were two research assistants in the same Faculty who provided support for peer-coding. One of them was conducting her dissertation research on technology related issues in mathematics education and the other on TPACK development of science teachers. Both of them were given two participants' final lesson plans, micro-teaching videos, and the transcribed version of their interview data. They were asked to match the codes prepared by the researcher with the numerated transcriptions. Their initial coding was aligned with the researcher's coding to the 88%. Then, the differences between the codings were discussed and the researchers reached total consensus. The analysis was finalized accordingly.

In order to provide transferability, the context of the study and the content of the implementation were described in detail as suggested by Fraenkel and Wallen (2006). Moreover, as mentioned by Yin (2003), the research report provided sufficient citation from all data sources about every theme and identified the conditions of and all procedures about the data collection process. Although there was no aim for generalizing the results obtained from this research, the aim of the research, purpose for selecting the participants, the preparation of data collection instruments, application of the data collection process and data analysis process, and the findings were reported in detail to provide researchers the insight of the study accurately.

4.7 Limitations and Assumptions

The findings of the study only represented the group of PMTs participated to the study through the TUME course. The study was limited with the time and the content of the TUME course. The PMTs and the researcher of the course had known each other before the course. Therefore, the PMTs might not have expressed their genuine thoughts in order to impress the researcher. The multiple forms of data collected in this study had the potential to reduce the effect of such behaviors on the study findings. With a more positive perspective, such relationship between the researcher and the PMTs might have led them to provide their true ideas during the study in order to help the researcher in her study. Accordingly, it was assumed that all participants provided honest and accurate information in the questionnaires, course discussions, written reflections, and interviews.

There were some pre-cautions taken to remedy for conducting unbiased interviews. Semi-structured individual interviews were conducted after the grading was completed and the semester ended, which was planned to ensure that participants responded the questions honestly. Nevertheless, to remedy distortional answers that would be caused by participants' familiarity with the researcher, the researcher asked each participant to provide real thoughts without any hesitation prior to every interview session. They were told that their actual ideas were of vital importance in this study which would be a part of the educational literature. Questions were prepared and directed to the participants in a friendly nature in order to fulfill Yin's (2003) definition of a qualified interview.

Participants' prior TPACK-P levels were determined in two domains: Assessment domain and Planning and Design domain. Their implementations of first lesson plans were not investigated. Therefore, TPACK-P proficiency levels in Enactment domain in the beginning of the TUME course could not be identified. Moreover, prior individual interviews were not conducted at the beginning of the course. Therefore, the researcher relied on participants' answers to the open-ended questions in the two pre-questionnaires and their initial technology-integrated lesson plans to identify their knowledge of technology integration and their TPACK-P levels. All participants' beginning TPACK-P levels were determined to be at level 1 in two domains. It was rational to assume that their TPACK-P levels in Enactment domain were the same with other domains or lower. Because the related literature emphasized that both pre-service and inservice teachers showed lower performance in implementating a technology-integrated plan than their knowledge of technology integration (e.g., Jen et al., 2016; Meagher et al., 2011; Mouza & Karchmer-Klein, 2013; So & Kim, 2009) and the quality of the lesson plan (e.g., Ay et al., 2016; Meagher et al., 2011).

Participants' instruction of their lesson plans through micro-teaching method was among the data sources of the study. Micro-teaching performances took place at the faculty classroom. Therefore, micro-teaching experiences lacked the facility of an authentic context. The reason was that, available middle schools for instruction were not equipped with technologies. If participants were to enact their lesson plans in mathematics classes in the middle schools, they would lack the opportunity to use the technology they intended to use. This was going to limit their choices which would be data loss for understanding their TPACK-P. Besides, micro-teaching provided teachers the opportunity to get reflections from their peers and to see examples of various technology integrated instructions from their peers' micro-teachings.

The pilot work of the TUME course was not conducted. The TUME course was desgined based on the principles of TPACK framework and TPACK-P framework. In addition, effective strategies identified in the related studies to develop TPACK in teacher education courses were utilized in the TUME course activities. Therefore, it was assumed in the beginning that the course would be effective for developing PMTs' TPACK-P. A pilot study of the TUME course and testing of the data collection tools would have provided more grounded interpretations. Therefore, these could be indicated as the limitations of the study.

4.8 Ethical Considerations

Official permission to conduct the research and use participants' documents was obtained from Ethical Committee of Middle East Technical University (see Appendix J). In addition, consent form informing participants about the aim of the study and permission for video recording (see Appendix K) was signed by each participant prior to the research. As it is a public report, throughout the research report, participants' names and the name of the institution that the study was conducted were hidden in this research report. Pseudonyms were used for each participant to ensure privacy. Codes from P1 to P11 were used to refer to each participant attended to the study.

CHAPTER 5

FINDINGS

The purpose of this study was to investigate pre-service middle school mathematics teachers' [PMTs'] technological pedagogical and content knowledge practical (TPACK-P) development through the undergraduate level course Technology Use in Mathematics Education [TUME]. In this chapter, the data gathered from multiple sources were analyzed to answer the following research question and the sub-questions:

1. How does the Technology Use in Mathematics Education Course influence pre-service middle school mathematics teachers' TPACK-Pdevelopment?
   a) What are pre-service middle school mathematics teachers' TPACK-P proficiency levels in the beginning of the Technology Use in Mathematics Education Course?
   b) What are pre-service middle school mathematics teachers' TPACK-P proficiency levels at the end of the Technology Use in Mathematics Education Course?

In this chapter, participants' beginning TPACK-P levels were reported first. After that, participants' individual progresses were identified in terms of levels proposed in the TPACK-P framework classified in three domains. Participants showing similar proficiency levels were grouped accordingly. The third part exemplifies and narrates plans, implementations, and views of the participants in each group. The results regarding each group were reported in separate sections.

5.1 PMTs' TPACK-P Levels at the Beginning of the TUME Course

Two questionnaires were implemented and a technology-integrated lesson plan was collected prior to the TUME course to identify participants' starting TPACK-P levels and to interpret their TPACK-P development at the end of the TUME course more accurately. The Views about Teaching Profession questionnaire provided information about participants' views about the importance of technology as part of teacher knowledge and competency both through teacher education and as in teaching profession. The Technology Usage Questionnaire revealed their experiences with and recognition about the facilities of educational technologies.

The answers provided for the questionnaires were analyzed through content analysis by focusing on technological knowledge and TPACK-P knowledge. The lesson plans were individually analyzed using the TPACK-P rubric to identify how participants utilized technology in a mathematics course design. In this part, participants' beginning levels were reported aligned with these analyses in the light of the data obtained from these sources.

5.1.1 Findings of Teaching Profession and Technology Usage Questionnaires

The analysis of the answers that the participants provided for The Views about Teaching Profession Questionnaire showed that all of the participants began the course with a similar image of being a teacher. Their views on teaching profession were basically being competent in subject matter knowledge, pedagogical knowledge, and experience in teaching.

Participants emphasized the necessity of competency in subject matter knowledge, which is mathematics content knowledge. For instance, P3 pointed out that a teacher *"should be well-equipped in his field, know every detail about the subjects, and develop himself continuously."* Most of the participants emphasized the importance of pedagogical knowledge by stating that subject matter knowledge is needed but not enough. The quote below illustrates this.

> It is not enough for a teacher to know merely about mathematics. He should also be skillful about how to transfer content to the students. Moreover, it is necessary

that the teacher chooses the right method by which the subject will be transferred to students. (P1)

Participants emphasized the crucial necessity of teachers' competency in pedagogical knowledge in relation with subject matter knowledge by mentioning some areas of competency such as *"methods and techniques used in transferring the subject*" (P2), *"identifying the mistakes that students can make and preventing beforehand"* (P3) by adapting several pedagogical approaches such as, *"connection with daily life"* (P7), *"managing students"* (P9), *"measurement and evaluation"* (P9), *"identify and consider students' individual differences and needs"* (P10), and *"being aware of that all students come with different level of readiness… designing the instruction accordingly"* (P11).

Some of the participants emphasized the importance of experience in teaching as a teacher competence and stated that *"teachers should be involved in lifelong development"* (P10) because *"accumulation of knowledge and experience are required"* (P4) to be a successful teacher. P10 also expressed that *"a teacher should always trust his knowledge, but he must be open to different ideas"* (P10) at the same time. The development was pointed to both through teacher education years and teaching profession.

Participants were asked what they would suggest for teacher candidates for developing themselves through their four-year teacher education program. They made various suggestions for PTs to improve themselves as competent teachers. They pointed out that PTs must be aware and focus on their professional development starting from the first year. Their suggestions were that PTs should *"be volunteer for teaching"* (P3), *"specialize in utilizing various types of materials such as technological tools"* (P9), and *"create various materials and activities in undergraduate courses"* (P8). They expressed these views about teacher education more than a suggestion and addressed them as absolute necessities if a PT wants to develop pedagogically.

Technology was only mentioned by P9 and P11 as a tool among other educational materials. P9 expressed that PTs would develop themselves in terms of developing and using materials such as technological tools. P11 stated that teachers should decide whether they would utilize technology and if so, they should plan how to use.

The second questionnaire was the Technology Usage Questionnaire. Participants' answers revealed how long they had been using computers, which technologies they were familiar with, and why they utilized them. Participants' duration of computer use changed from 3 to 18 years. P9's computer experience was the least among others which was three years. She was a transfer student from Mathematics Department of a public university. She had been using computers in education since she enrolled to the Faculty of Education three years ago. P3's experience with computers was the highest among others which was 18 years. She expressed that she had been playing video games on computer since she was a child. The technologies participants mentioned were presented in Table 5.1.

Table 5.1

The Technologies Participants Used

	Technologies	Participants	N
1	Calculator	P1 – P11	11
2	Projector	P1 – P11	11
3	Poster preparation programs	P2, P3, P4, P6, P7, P11	6
4	Microsoft office programs	P1, P2, P8, P9, P10	5
5	Smart Board	P1, P6, P10, P11	4
6	GeoGebra	P6, P8, P11	3
7	Video edit programs	P3, P4, P7	3
8	Comics preparation programs	P3, P7	2
9	Puzzle preparation programs	P3, P7	2
10	Social network websites	P4, P6	2
11	Websites	P1	1
12	C plus	P2	1
13	C sharp	P2	1
14	Fireworks	P2	1
15	Concept map preparation programs	P4	1
16	Animation preparation programs	P4	1
17	Test preparation programs	P4	1
18	Prezi	P4	1

As it can be seen on Table 5.1, all of the participants mentioned calculators and projector as the technologies they use in education. They wrote that they used calculators in Probability and Statistics course and instructors in the program were using projector which existed in all classrooms in the Faculty. Six participants mentioned poster preparation programs without referring to a specific program. Only five participants mentioned Microsoft Office Programs although all of them had used Microsoft Word to write reports and Microsoft Powerpoint to prepare presentations in the previous semesters. Four participants noted that the instructor used Smart Board in Computer Skills I and II courses. Three participants mentioned they were introduced with GeoGebra in an elective course. They mentioned that they were introduced with animation, concept map, test, poster, puzzle, comics creation programs, and video edit programs in Instructional Technology and Material Design course. They also used computers and several programs on computer in Computer Skills I and II courses. P2 was a transfer student from Faculty of Engineering and mentioned C plus, C sharp, and Fireworks programs which she was introduced there.

Table 5.2

The Aims for Using Technologies

	Aims of Use	Participants	N
1	To make presentations	P1, P3, P4, P5, P9, P10, P11	7
2	To make research	P3, P4, P5, P6, P7, P8, P10	7
3	To prepare course assignments	P1, P2, P4, P6, P9, P11	6
4	To prepare posters	P2, P3, P4, P9, P11	5
5	To play games	P1, P3, P6, P7, P11	5
6	To make complicated calculations easy	P5, P8, P11	3
7	To create comics	P1, P3	2
8	For educational aims	P2, P4	2
9	To prepare puzzles	P3	1
10	To edit videos	P3	1
11	To watch videos	P3	1
12	To prepare concept maps	P4	1
13	To prepare tests	P4	1
14	To explore the coordinate axis	P6	1
15	To draw graphs	P8	1
16	To draw geometrical shapes accurately	P11	1
17	To socialize	P6	1
18	To read news	P7	1
19	To send e-mails	P9	1

Participants stated purposes for using some of the technologies they mentioned. They mentioned reasons of technology utilization both for their own uses as students and their instuctors' uses. Some of them stated reasons by specifying the kind of technology whereas some of them mentioned only the aims of use without mentioning a certain technology. The aims of use were listed in Table 5.2 without specifying the technology.

Participants seemed to be aware of many technologies and they had been using some of them for educational purposes. The most stated purposes were making presentations via projector and making research on the Internet. Six participants stated that they used computers and technology for preparing course assignments such as writing reports. Three participants referred to calculator use in Probability and Statistics course to make complicated calculation easier. P8 mentioned drawing graphs and P6 mentioned making exploration on coordinate axis as the purposes of using GeoGebra. P11 stated that Smart Boards can be utilized for drawing geometric shapes accurately. Utilizing computers for the Internet use was mentioned by P6, P7, and P9 for the aims of socializing, reading news, and e-mailing. Most of other purposes were linked with the technologies they were introduced in Educational Technology and Material Design course.

5.1.2 Initial Lesson Plans

Participants were assigned to prepare technology-integrated lesson plans. Analysis of the initial lesson plans provided data about participants' beginning TPACK-P levels. Their plans were analyzed for Assessment domain and Planning and Design domain in TPACK-P framework. The Enactment domain was neglected since they did not implement these lesson plans. P2 and P9 designed lesson plans for measurement of the area of a parallelogram and division of fractions, respectively, topics at the 6^{th} grade level. They did not mention about utilization of any technologies in the lesson plan. P7 did not submit the first lesson plan. The plans submitted by P8 and P10 showed close similarity with plans in an online teacher platform. Therefore, they were not analyzed. The mathematics topic and the grade level, type of technologies integrated to the lesson plan and the teaching strategies selected in each participant's lesson plan were presented in Table 5.3.

Table 5.3

The Content of Technology-Integrated Initial Lesson Plans

Participant No	Grade - Topic	Type of technology	Pedagogical strategy integrated with technology
P1	8 – Similar triangles	Powerpoint, projector, and GeoGebra	Lecture, question and answer, student-centered
P2	6 – Measurement of the area of a parallelogram	–	–
P3	5 – Properties of triangles and rectangles	Video	Demonstration, teacher-centered
P4	7 – Linear equations with one unknown	Powerpoint and projector	Demonstration, teacher-centered
P5	7 – Integers	Video	Demonstration, teacher-centered
P6	6 – Converting fractions to decimals	Powerpoint	Demonstration, teacher-centered
P7	–	–	–
P8	–	–	–
P9	6 – Division of fractions	–	–
P10	–	–	–
P11	6 – Area of a parallelogram	GeoGebra	Construction, teacher-centered

Powerpoint integration was suggested by three participants for visual demonstration of content. P1 designed a lesson plan which did not include information about the learning and teaching process. She provided information about the grade, the learning area and objectives, the materials, and the aim of the course. At the end of the plan she noted that she suggested the use of Powerpoint and projector but did not mention how she planned to utilize them. P4 mentioned supporting the instruction by visual demonstrations of linear equations on

Powerpoint to take students' attention. Moreover, she suggested that "*more materials could be prepared to enrich the plan which could enhance students' understanding of the subject by addressing individual differences.*" However, she did not mention any technology-integrated materials. P4's initial lesson plan was provided as an example in Appendix L. P6 designed a course about converting fractions to decimals. She planned to use Powerpoint to demonstrate the different representations of fractions. She explained the aim by mentioning the concretization of the subject. However, she neither explained how to achieve this aim, nor identified the content of the Powerpoint.

Utilizing GeoGebra was mentioned by three participants for demonstration and construction purposes. P1 noted that she planned to utilize GeoGebra for demonstrating similarity of triangles. She stated that she would "*initially introduce definition of a triangle, how it is constructed, and the triangular elements on GeoGebra*". She mentioned that GeoGebra should be used to achieve these aims in a student-centered environment in a computer laboratory. In contrast with these statements, she ended the plan with an instruction that "*triangles will be drawn with the help of a ruler in the sample questions*" which was a construction and not supported with GeoGebra as she stated before. There was no further information about instructional tips for construction on GeoGebra. P11 suggested GeoGebra utilization to teach the area of a parallelogram. She mentioned that GeoGebra supported learning by visual presentation of the subject as follows:

> They [students] learn the properties of geometric shapes and calculation of the area often by rote learning. But the teacher, who teaches these subjects by utilizing this program [GeoGebra], can explain and present the height and area of the parallelogram more visible and more concrete. (P11)

Two participants used videos on their lesson plans to motivate students and summarize the content. P3 designed a lesson plan about the properties of triangles and rectangles for 5^{th} grade. She utilized a YouTube video in the beginning of the course about only the basic properties of a triangle and visuals of triangles. These properties were about the sides and the vertices of a triangle. There was a song in the video which was describing two properties of triangles in rhyming clauses. There was no statement about other properties such as angles. There was no technology utilization for the other objectives which were the properties of quadrilaterals and construction of triangles. P5 suggested demonstration of videos about integers at the end of the lesson to summarize the properties of integers.

There was no technology integration for assessment and evaluation aims. The plans were also analyzed for prior and end of course assessments. There were problems in the lesson plans to be solved through the course. However, there was no sign that these problems were planned for measuring students' mathematical knowledge, learning styles, needs, or difficulties.

5.1.3 Beginning TPACK-P Levels

Participants' initial TPACK-P levels were identified for two domains, the assessment domain and the planning and design domain. Participants' responses to the two questionnaires and the content of the technology-integrated lesson plans were considered to identify their initial TPACK-P levels. The data were analyzed to identify participants' beginning TPACK-P levels by considering the indicators and behaviors in the TPACK-P rubric which was presented in the previous chapter.

There was no emphasis on technological knowledge among the answers participants provided for the two questions in The Views about Teaching Profession Questionnaire. It was evident that participants did not consider technology as a teacher knowledge type such as pedagogical knowledge and content knowledge. Technology was only mentioned by P9 and P11 as a tool among other educational materials without expressing the facility or need for it.

Answers provided for Technology Usage Questionnaire revealed 18 types of technologies that participants knew about and used before. Preparing presentations, posters, puzzles, concept maps, and tests, drawing graphs and geometric shapes, exploring coordinate axis, and making calculations were among the educational aims of technology use. Each participant indicated at least two of these goals. Although there were a broad range of technologies that they were aware of and that they had used for several educational aims, they did not utilize them in their lesson plans.

The technologies mentioned in the lesson plans were Powerpoint, projector, GeoGebra, and video. Yet, P2 and P9 could not integrate any technologies to their lesson plans and P7, P8, and P10 did not even submit an original technology-integrated lesson plan. Six participants who suggested the use of technology in the lesson plans could not express details of these uses. The goals were concretization and visualization of the concepts, motivating students, and summarizing the subject. However, they could not specify the content of the technology-integration and how to integrate and implement. Powerpoint and projector were suggested for demonstration of mathematics content visually by P1 and P4. In addition, P6 suggested Powerpoint use but did not mention how she planned to utilize it. GeoGebra was suggested for demonstration of similarity of triangles and visual representation of area of a parallelogram. Video was suggested for motivating students and to summarize the subject. P3 suggested a video in which two properties of triangles were presented as a song. In this way, the use of technology was reinforcing but not essential. The aims of technology integration suggestions were accurately insufficient in terms of technology affordances and inadequate for meeting the course objectives. The technologies were incompatible with the mathematical content. In other words, the selected technologies and content were separate entities. Moreover, the pedagogical strategies matched with the selected technologies were undefined.

Technology was planned to be used only in a limited part of the course in the lesson plans. There were no examples of technology utilization to provide students for constructing their own knowledge. Five among six plans with technology suggestions were examples of teacher-centered uses of the technology. Only P1 suggested the use of GeoGebra in a student-centered environment. P1 designed a relatively better technology-integrated course plan by suggesting the use of Powerpoint and construction on GeoGebra in a student-centered environment. Although these suggestions referred to a higher level TPACK-P, the plan lacked instructional details for implementation such as the aim of using these technologies, the steps and guidance to implement, the content and details of the activity, the role of the teacher, and expectations from the students. In addition, the subject was planned to be taught on GeoGebra with individual performances of students in a computer laboratory. While it was appropriate to solve the questions on GeoGebra according to the flow of the course, she advised the use of ruler for drawing triangles while solving problems. She used drawing and measurement functions of GeoGebra rather than its functionality of dynamic environment and multiple representations.

According to the responses to the Technology Usage Questionnaire, it appeared that all participants were aware of various technologies and had used them for educational purposes in some of the other courses. However, they did not mention technology as a teacher competency in their responses to questionnaires. Only P9 and P11 mentioned technology by referring it as a tool. Although the participants recognized and used several technologies, their choices of technology in their initial lesson plans were inadequate. They did not utilize technology to contribute to the lesson design more than the current strategies and designs. They also used technologies in limited facilities. According to these findings, it was decided that all participants were at level 1 in the Planning and Design domain of TPACK-P. In addition, there was no participant who mentioned technology use for assessment and evaluation purposes neither in lesson plans nor in the questionnaires. Therefore, all participants were considered to be at level 1 in the Assessment domain.

5.2 PMTs’ TPACK-P Levels at the End of the TUME Course

Participants’ TPACK-P levels were determined according to their second lesson plans, micro-teaching videos where they enacted the course in their lesson plans, the peer and self assessment forms filled by their peers and by themselves considering their micro-teaching, and the individual interviews after they completed all of the TUME course requirements. The TPACK-P rubric was filled for every participant separately by using the data from these sources respectively. The rubric is comprised of TPACK-P indicators and exemplary teacher actions. The TPACK-P indicators were presented by Jen et al. (2016) and these indicators were based on the TPACK-P proficiency levels presented by Yeh et al. (2015). Jen et al. (2016) provided exemplary teacher actions and views to clarify the meaning of each indicator. In the present study, these indicators were modified and converted into a rubric form. The rubric was presented in the previous chapter. The analysis revealed each participant's final TPACK-P levels. Participants' TPACK-P levels were presented in Table 5.4 regarding the three domains of TPACK-P.

Table 5.4

TPACK-P Levels of the Participants at the End of the TUME Course

Levels	Assessment	Planning and Design	Enactment
4: Reflective Application	P2, P6, P11	P1, P11	P1, P11
3: Infusive Application	P1, P3, P4, P5, P7, P8, P9	P2, P3, P5, P6, P8, P9	P2, P5, P6, P8
2: Simple Adoption	P10	P4, P7,P10	P3, P4, P7, P9, P10
1: Lack of Use			

Participants' TPACK-P levels differ in three domains. For instance, P2 and P6 progressed at level 4 for assessment domain whereas they progressed at level 3 in planning and design domain and enactment domain. There were participants whose performance pertained to the same level in all domains. For instance, P11 performed at level 4 in three domains. There were no participants detected at level 1.

Each participant designed a technology-integrated lesson plan which supposed to address effective teaching of a middle school mathematics subject and they performed their plans to their peers in the classroom. Participants determined the mathematics objectives, the technologies and the teaching and learning strategies without any restrictions. Table 5.5 presents the technologies that participants utilized to transform the mathematics subjects with the teaching and learning strategies.

Table 5.5

The Content of Course Designs and TPACK-P Levels

Participant	Grade and Subject	Technology	Teaching and Learning Strategy	TPACK-P Level		
				Assessment Level	Planning & Design Level	Enactment Level
P1	6 – Measurement of area of a triangle	GeoGebra Socrative	Student-centered Activity-based Collaboration Demonstration	4	4	3
P2	6 – Measurement of area of a parallelogram	Posters via Powerpoint and Glogster Smart Board Kahoot	Student-centered Demonstration Discovery learning Discussion	4	3	3
P3	5 – Properties of triangles and rectangles	Video via YouTube Smart Board Socrative	Student-centered Activity-based learning Demonstration Collaboration Discussion Question and answer	3	3	2
P4	8 – Exponential numbers	Worksheet via Microsoft Word Kahoot	Teacher-centered Question and answer Discussion	3	2	2

Table 5.5

The Content of Course Designs and TPACK-P Levels (continued)

Participant	Grade and Subject	Technology	Teaching and Learning Strategy	TPACK-P Level		
				Assessment Level	Planning & Design Level	Enactment Level
P5	5 – Addition of fractions	Video via YouTube Kahoot	Student-centered Modeling Demonstration Collaboration Activity-based Question and answer Discussion	3	3	3
P6	8 – Geometric solids	Pinterest Presentation via Powerpoint Kahoot	Student-centered Discussion Collaboration Activity-based Question & answer	4	3	3
P7	5 – Calculation based estimation	Calculator Socrative	Teacher-centered Problem-solving Question and answer Estimation Discussion Reasoning	3	2	2

Table 5.5

The Content of Course Designs and TPACK-P Levels (continued)

Participant	Grade and Subject	Technology	Teaching and Learning Strategy	TPACK-P Level		
				Assessment Level	Planning & Design Level	Enactment Level
P8	7 – Measurement of perimeter and area of a square	Smart Board Kahoot	Activity-based Collaboration Brainstorming Demonstration Reasoning	3	3	3
P9	8 – Pythagoras theorem and special right-angled triangles	Video via YouTube Smart Board Socrative	Student-centered Demonstration Visualization	3	3	2
P10	5 – Measurement of length	Kahoot	Teacher-centered Visualization Discussion	2	2	2
P11	7 – Properties and measurement of area of a parallelogram	GeoGebra Socrative	Student-centered Activity-based Demonstration Question and answer	4	4	4

Participants determined objectives from 5^{th} to 8^{th} grade curriculum. They used one of the online assessment programs Kahoot or Socrative for end-of-course assessments. Presentations via Powerpoint and Pinterest and posters prepared by Powerpoint and Glogster were used as pre-assessment tools to determine student needs and prior knowledge. Other technologies served for different purposes in transforming the given mathematics subject. Participants applied many teaching and learning strategies in their course designs and implementations. However, only the strategies they integrated when utilizing technology were reported under the Teaching and Learning Strategies section in Table 5.5 for each participant separately. TPACK-P levels belonging to each TPACK-P domain were also presented in Table 5.5.

5.3 PMTs' TPACK-P Progress in Clustered Groups

The TPACK-P rubrics for eleven participants showed that a participant having a high level in a domain can be at a lower level in other domains. Participants were clustered according to the interpretive results of their TPACK-P levels. They were included in three groups which were Mostly Simple Adoption group, Mostly Infusive Application group, and Mostly Reflective Application group. P4, P7, and P10 were included in Mostly Simple Adoption group. P10 showed stable progress at level 2 in all three domains. Hence, P10 was accurately at Simple Adoption Level. P4 and P7 were counted in this group as they performed at level 2 in two domains which are planning and design domain and enactment domain. P5 and P8 showed performance corresponding to level 3 – Infusive Application Level – in all three domains. Although P2 and P6 performed at level 4 in assessment domain, they were included in the Mostly Infusive Application group for performing at level 2 in other two domains. In addition, P3 and P9 were included to this group for performing at level 3 in two domains, which are assessment domain and planning and design domain. Therefore, P2, P3, P5, P6, P8, and P9 together formed Mostly Infusive Application group. P11 performed at level 4 in three domains. Differing from P11, P1 performed at level 3 in assessment domain. P1's performance was also included to be aligned with P11 as she was at level 4 for other two domains. Therefore, P1 and P11 were grouped as Mostly Reflective Application.

Detailed explanations were provided about the TPACK-P development of each group in three separate sections below. Participants' practices and behaviors in each group were narrated to provide a holistic picture of their progress and TPACK-P levels. The explicit and detailed narrations of PMTs' knowledge and applications were provided to identify the influence of the TUME course on PMTs' TPACK-P levels which presented the answer of the research question in the study.

5.3.1 Group 1: Mostly Simple Adoption

Participants included in the Mostly Simple Adoption group were P4, P7, and P10. As mentioned earlier in this chapter, P4, P7, and P10 progressed at level 1 at the beginning of the TUME course (Table 5.6). Compared to the beginning of the course, their TPACK-P was slightly developed. In other words, the end-of-course levels tell that they could not demonstrate and perform intended technology instruction in mathematics education. Their knowledge and progress in three domains of TPACK-P were explained in detail aligned with the principles of TPACK-P framework.

Table 5.6

TPACK-P Levels of the Participants in Mostly Simple Adoption Group

Levels	Assessment	Planning and Design	Enactment
4: Reflective Application			
3: Infusive Application	P4, P7		
2: Simple Adoption	P10	P4, P7, P10	P4, P7, P10
1: Lack of Use			

5.3.1.1 Assessment Domain

In the assessment domain, the highest level of TPACK-P anticipates teachers to assess and evaluate students in terms of their mathematics knowledge both before and after the instruction through utilizing various representations provided by appropriate technologies. According to TPACK-P framework, besides assessing student knowledge of mathematics, the assessment is expected to identify students' learning needs and styles to design and implement effective instructions. This is the highest performance expected from teachers in assessment domain in TPACK-P framework. However, the basic characteristic of PTs in this Mostly Simple Adoption group is that they assessed students' mathematics knowledge only by presenting mathematics content through technology. Online assessment platforms were used for summative assessment at the end of teaching with no effort to use multiple representations.

P4 and P10 used online assessment programs to offer students repeated practices about the mathematics content. P4 prepared and implemented a quiz comprised of 8 comprehensive questions about exponential numbers to assess students' mathematics knowledge at the end of the instruction. Although the questions were comprehensive for exponential numbers subject in 8th grade, they were routine questions about calculating positive and negative exponents of natural numbers. P4, P7, and P10 used multiple-choice question and true-false question that Kahoot offered and open-ended question that Socrative offered. It was allowed to attach photos to the questions in Kahoot and Socrative. However, participants did not use different representations in the questions although they learned in the TUME course in the 6th activity which was the Evaluating Student Learning activity. Participants utilized Kahoot and Socrative as assessment tools that provide instant feedback and record students' progresses for each question. P4, P7, and P10 discussed with peers about true and false answers relying on this detailed performance feedback through using question and answer technique. In the discussions, the instructing participants asked peers to explain the solution of each question and search for the possible reasons of wrong answers that appeared on the detailed feedback report.

In addition to assessing mathematical knowledge, P4, P7, and P10 took advantage of online assessment programs to enhance participation of students with different backgrounds and motivations. P10 indicated in the interview that she featured all online assessment programs for providing students with reinforcement and motivation to participate. In her instruction, she utilized the online assessment program Kahoot. She prepared a quiz consisting 6 questions on Kahoot. With a similar aim, which is to motivate his peers, P7 assigned an attractive name as the room name in Socrative which was in the meaning of “the teacher’s class”. Besides the aim of motivating learners, it was evident that P10 was also motivated as a teacher to use online assessment programs. Confirming this, she indicated in the interview that Kahoot is a user-friendly assessment program for teachers. As a support to P10’s motivation to use online assessment programs, all participants in this group considered online assessment programs as user-friendly for both teachers and students. They all mentioned in the interviews that as a teacher it is easy to prepare quizzes either premeditated or instantly-decided through utilizing different types of question formats. P4 indicated in the interview that from the time she met online assessment programs in the TUME course, she had been using Kahoot in her private courses for several reasons.

> Kahoot application is easy to use and motivating. It is attention grabbing. Its music and font takes attention on the subject for presenting content. Moreover, it forms a competitive environment that enhances participation. (P4)

P7 preferred to use Socrative instead of Kahoot. He explained why he preferred Socrative in his micro-teaching in the interview. He stated that he attended one of his peers quiz in the Evaluating Student Learning activity in the TUME course and there was a question in the quiz in which geometric shapes were the answer options. Kahoot also uses geometric shapes to represent the options. As the quiz was conducted on Kahoot, both the answer buttons and options were geometric shapes. This was confusing and he struggled when answering the questions in that geometry quiz.

> There was a question about the geometric shapes that compose hexagonal prism. I immediately selected the triangle option on the Kahoot screen. However, the option was not representing triangle. So, I answered wrong. (P7)

P7 expressed that, Socrative had a more formal interface compared to Kahoot, thereby appropriate for middle school level.

Timing in Kahoot was criticized by P4’s peers in her micro-teaching and was mentioned in the peer-assessment forms. Similarly, the answer time limits assigned to the questions in the quiz conducted by P10 were very short that all of her peers criticized. In the interviews, P4 and P10 reflected on their timing problem about their online quiz implementation via Kahoot. They mentioned that it was important to manage suitable time limits considering the students' needs.

In the interview, P4 stated that she intended to assess students in the beginning of the course to identify their prior knowledge. This was an intended action of TPACK-P corresponding to level 3 in assessment domain. However, for her micro-teaching, she did not plan or implement an assessment regarding this aim. P10's utilization of technology in assessment was in accordance with the indicators of level 2, a lower level than P4 and P7. The reason was that P10 used online assessment program to reinforce participation by motivating learners. Unlike P10, P4 and P7 pointed out to the classroom performance on the performance report that the online assessment programs provided and used the results to discuss about wrong answers.

5.3.1.2 Planning and Design Domain and Enactment Domain

For planning and design domain and enactment domain, participants in the Mostly Simple Adoption group planned and designed instructions to develop students' understanding and increase students' learning motivation. They presented mathematics content through appropriate and available technological tools with suitable instructional strategies. P4, P7, and P10 demonstrated TPACK-P at level 2 both in planning and design domain and enactment domain.

P4 designed activities and explained them in her lesson plan. However, she did not integrate any technologies in the activity plans. Although the researcher provided feedback to enhance the lesson plan in terms of technology support, there was no improvement in her final lesson plan. Similarly, in the peer-assessment forms, eight of her peers expressed that material support and technology-integration was needed to enhance the instruction. She accepted this criticism in the interview. However, she hardly provided suggestions for a technology-supported material. She expressed that exponential numbers subject in 8^{th} grades was not appropriate to teach via technological tools that she was familiar with. She only pointed that her micro-teaching was inadequate in terms of visualization. Similar to

P4, P7 mentioned the lack of visualization in his instruction while watching his micro-teaching video prior to reading the peer-assessment forms. He expressed that he should have prepared a poster showing the types of estimation strategies and their applications on visually-represented daily-life problems. He also suggested the use of online games as tools that visualize mathematics and motivate learners. He mentioned that he would use them in the future when teaching patterns subject.

Lack of supportive technological tools was mentioned by P7's peers, too. In the peer assessment forms, P1 suggested using posters and P6, P9, P11 suggested the use of calculators. P7 mentioned using calculators in his lesson plan about calculation-based estimation subject belonging to 5th grade. However, there was no explanation about how and in which part of the course he was going to utilize calculators. Because of being unprepared, he could not integrate calculators to the instruction. In the interview, he criticized his micro-teaching and stated that he should have supported his instruction by using calculators.

> When I watch now, I think the subject was not understood at all. I should have used a calculator to calculate the actual results of the problems. Then, they (peers) would have developed ideas about the nearest result of the problem. In the end, they would have discussed the reason of the different results referring to the guesses and the result on the calculator. (P7)

As stated in the quote above, P7 planned to integrate calculators while solving problems about calculation-based estimation subject through discussion and reasoning instructional strategies. In addition, P7 stated that he would utilize online games in the beginning of a mathematics course to show the concept as a whole. He also expressed that he implemented the same lesson plan in the Methods of Teaching Mathematics course in the previous year. He mentioned using Prezi presentation program in that implementation. Moreover, he used Piktochart in the Poster Preparation activity in the TUME course. Although he was good at preparing presentations and using presentation technologies, he did not use a presentation considering that the level of students was not appropriate as in the following excerpt.

> My implementation was based on daily life situations. For instance, 'in which situations do you make a guess?' was one of the warm up questions. Moreover, the examples in the plan were prepared considering their [students'] mathematical

> knowledge levels. Presentation is not suitable for 5th grades. If I was not teaching to this level [5th grade], I would not have taught teach this way. (P7)

P4 distributed two worksheets which she prepared digitally by Microsoft Word. One of them was for summarizing the key points of the subject and one included questions about exponential numbers. In the interview, she expressed that providing students with a summary of the content at the beginning of the course was important to motivate them more on learning. In addition, she highlighted that this summary including the key points should be determined and prepared by the teacher through word processors to be neat, accurate, and comprehensible. In the interview she suggested this to increase student motivation.

P10 started the instruction with a warm-up question of how the length of a water bottle can be measured. Then, she hanged cardboards on the wall that had geometric shapes on it and asked peers to find their perimeters by using a ruler. In the interview, P10 criticized her micro-teaching and stated that she would have used GeoGebra instead of cardboards. Her suggestion was a teacher-centered implementation where only the teacher uses GeoGebra for demonstration. P10 also stated that she would have used a poster about length measurement units to be used in the time of teaching and afterwards to stay on the bulletin board of the classroom. Preparing a poster was also suggested in peer assessment forms. Confirming this, P1 also indicated that P10 should have supported the implementation with technologies such as a poster to visualize the subject. Peers criticized that the implementation should have been supported with technology to enhance learning.

P4, P7, and P10 planned and implemented teacher-centered lessons. Their technology-integrated lesson plans and micro-teaching implementations were strong in terms of content, but weak in terms of technology integration and student-centered implementation. Although participants were given the opportunity in the interviews to criticize their instruction through watching their micro-teaching videos and reading the peer-assessment forms, they did not suggest any student-centered strategies in supporting their micro-teaching plans with technology.

P7 was good at solving technical problems about technological tools. For instance, in his micro-teaching experience, Socrative gave feedback to all answers as false. He immediately found and fixed the problem which was about selecting more than one true answer in the answer key. In the interview, he stated that he can easily inform teachers about how to use a technology. P10's doubts were explicit in the interview. She stated that *"I feel confident in using only the technologies I met in the (TUME) course."* She added that she was also confident in considering herself as a leader to teach other teachers how to use these technologies. She stated that *"in the future I will definitely adapt these technologies in teaching all of the related mathematics subjects in my courses."* The advantages she pointed were motivation and gaining time. Likewise, P4 was confident in using technologies in teaching mathematics. She expressed that she would use poster and Pinterest website to visualize concepts and to foster permanent learning and use online games to reinforce students in her future teaching career.

5.3.1.3 Summary of TPACK-P Progress

As an overall review, participants in the Mostly Simple Adoption group tended to utilize technology to assess mathematics learning by providing repeated practices in a motivating platform to enhance participation. They basically considered using online assessment programs for their physical properties such as sound and font in Kahoot (P4), formal appearance of Socrative (P10), and being user-friendly both for students and teachers (P4, P7, and P10). All of them prepared comprehensive questions and were able to use different question types that the programs offered. The time given to each question was not determined accurately in the online assessment implementations (P4, P10).

They particularly emphasized technology integration in their plans and interviews to present mathematics content digitally for increasing student motivation towards learning mathematics. P4 prepared worksheets in Microsoft Word for summarizing the key points of and presenting example questions about the exponential numbers subject; P7 planned using calculators in teaching estimation strategies subject; and P10 suggested using GeoGebra in measurement of length subject to impress students and make instruction easier. Moreover, P4, P7, and P10 and their peers mostly criticized their instructions for the lack of visualization. To fill this need, they suggested preparing posters (P7, P10) and utilizing GeoGebra (P10). They reflected positive views on utilizing technology to enhance instruction and promote student learning. Their views about integrating technology were teacher-centered as well as their plans and micro-teaching implementations.

5.3.2 Group 2: Mostly Infusive Application

Participants in Mostly Infusive Application group were P2, P3, P5, P6, P8, and P9. As mentioned earlier in this chapter, these participants progressed at level 1 at the beginning of the TUME course. According to the analysis of the data obtained during and at the end of the course, their overall TPACK-P performances were aligned with level 3, named as Infusive Application Level in TPACK-P framework (Table 5.7).

Table 5.7

TPACK-P Levels of the Participants in Mostly Infusive Application Group

Levels	Assessment	Planning and Design	Enactment
4: Reflective Application	P2, P6		
3: Infusive Application	P3, P5, P8, P9	P2, P3, P5, P6, P8, P9	P2, P5, P6, P8
2: Simple Adoption			P3, P9
1: Lack of Use			

As it can be seen in Table 5.7, P2 and P6 performed at level 4 in assessment domain whereas they were detected at level 3 in planning and design domain and enactment domain. P3 and P9 performed at level 3 in assessment domain and planning and design domain. However, they performed at level 2 in enactment domain. P5 and P8 were at level 3 in all domains. Hence, compared to the beginning of the course, there was a considerable development in their TPACK-P. The end-of-course levels tell that they could select and use appropriate technology for evaluation reasons; design and implement technology-supported effective instructions with respect to the needs of students to develop mathematical learning. In this section, participants' knowledge and progress in Mostly Infusive Application group were explained in detail aligned with the principles of TPACK-P framework.

5.3.2.1 Assessment Domain

The basic characteristic of PTs in the Mostly Infusive Application group in terms of assessment domain is that they assessed and evaluated student performance not by merely presenting mathematics content through technology but presenting difficult subject content in diverse and efficient ways such as presenting dynamic content through multimedia. The aims were to identify students' learning styles and learning difficulties and to assist student learning by utilizing various representations provided by appropriate technologies. Additionally, some participants used technology to identify students' learning needs and styles which led to design instruction accordingly. This is identified as one of the highest level assessment aims in TPACK-P.

Participants conducted technology-assisted assessments in the beginning of the instruction to assess prior knowledge, to identify learning needs, and to design the instruction accordingly. To start with, P2 instructed a course about measuring the area of a parallelogram at the 6th grade level. She designed a poster about the basic geometric shapes as shown in Figure 5.1.

Figure 5.1 P2 presenting her poster about area of basic geometric shapes

She initiated the course by presenting this poster. She asked questions about the properties of and relationship between a triangle, a square, and a parallelogram relying on the visual representations of figures with different sizes on the poster. Then, she guided the participants to draw parallelograms and tell any properties that they can infer from their drawings. By doing these two linked activities, P2 assessed learners' readiness and needs. She mentioned in the interview that 6th grade students were equipped with the knowledge of properties of the triangle and the parallelogram and the poster possessed her aim to remind them about this prior knowledge linked with the new subject. Hence, she was able to detect and remind any missing information considering the properties of a parallelogram before teaching the area of a parallelogram. She suggested that this poster could be copied in notebook size and distributed to students to be pasted on their notebooks as a course note rather than only hanging on the wall. This was another pedagogical aim of utilizing the poster. Although she used a poster formed by her drawings with paper and pencil, she expressed that she would use Powerpoint or Glogster to prepare the poster with proper drawings of geometrical figures when she would teach to 6th graders.

P6 also used technology support to detect prior knowledge. She initiated the instruction by a Powerpoint presentation about geometric solids. The presentation was comprised of pictures of several geometric figures from daily life which she gathered from Pinterest. One of them was a clock figure composed of polygon shapes in the place of hours. She addressed questions about the relationship between the properties of the polygons and the hours they correspond to. She guided and managed a classroom discussion on this question. This enabled P6 to identify participants' prior knowledge and misunderstandings about geometric solids. She emphasized in the interview that she would use a presentation in the beginning of the course for identifying and remedying the learning needs about prior knowledge.

> If there are students with deficient learning backgrounds about geometry I will prepare a Powerpoint presentation and use it at the beginning of the course. The aim is to remind them prior knowledge linked with the new subject. (P6)

P3 planned and designed a course about basic properties of triangles and rectangles subject in 5th grade. P3's lesson plan was provided in Appendix M as an example. She used technology support with the same aim with P6 which was to determine prior knowledge and learning needs. She conducted an origami activity in the beginning of the instruction. She supported the activity by a demonstrative video from YouTube. P3 implied that she utilized the video to assist students with different learning styles by providing visual representation of the activity. She directed several questions about the shapes occurred every step on the video through question and answer technique. Some of these questions were *"Which geometrical shape is this?"*, *"How many diagonals do this geometrical shape have?"*, and *"What are the angles of the triangle occurred after folding the paper precisely overlapped?"* This allowed P3 to identify learning needs accordingly. She manipulated and arranged all upcoming steps of the origami activity according to the answers and progresses of the participants. When answers were incomplete or wrong, P3 gave another instruction and rewound the video according to the misunderstandings and needs of the participants. Although these applications were not examples of assessment through technology directly, YouTube video mediated assessing prior knowledge, identifying learning needs, and shaping the following steps of the instruction.

P5 mentioned the importance of starting every course by assessing and reminding about prior knowledge connected with the new subject in the interview. She commented on her micro-teaching by comparing it with the same course she implemented in the collaborating middle school. She expressed that she considered her experiences with the students in the collaborating school when she was preparing the lesson plan. According to her statements in the interview, she identified the needs and expectations of middle school students regarding the fractions subject and finalized the planning of micro-teaching accordingly. However, she did not utilize technology for evaluation purpose prior to the course.

P8 did not conduct any technology-assisted assessments in the beginning of the instruction. She designed and enacted a course about square concept from the geometry and measurement learning area corresponding to 7th grade. The plan covered perimeter and area of a square. She directed warm up questions about properties of a square by referring to examples from daily life. For instance, she asked *"Can you mention square shapes from the tools you use in your daily life?"* and *"How do you decide that it is a square?"* While doing so, P8 aimed to identify participants' prior knowledge about squares. However, she did not support this step with technology to help students to answer. This restricted the question-answer part within students' few answers about square shapes they could think of at that moment. P9 implemented a similar prior assessment part. She directed warm up questions about Pythagoras theorem and right-angled triangles without technology support.

All of the participants in the Mostly Infusive Application group assessed and evaluated mathematical knowledge through online assessment programs at the end of the implementations. They constructed quizzes including different problem types supported with multiple representations to assess and evaluate mathematical knowledge and to identify individual and diverse student learning. P3 used Socrative assessment program. She indicated that her aim was not only to assess knowledge but to revise the subject and identify and support students' learning. Confirming this, P11 expressed in the peer-assessment form that P3 used Socrative both to assess their learning and revise the subject by presenting different problem types such as true-false, open-ended and multiple choice regarding the content. Similar to P3, P9 expressed that Socrative was useful to assess and evaluate students' knowledge, to identify students' needs, and to determine whether the subject was understood and implemented well.

P8 utilized Kahoot for the end-of-course assessment. She conducted a quiz consisting 10 questions. She mentioned that she tried to prepare an extensive set of questions about the measurement of perimeter and area of a square subject. She used various representations in the quiz such as verbal, algebraic, and model representations about squares. Her peers also mentioned the quality of comprehensive questions in P8's quiz. Similarly, P5 and P6 prepared quizzes on Kahoot online assessment program. P5 mentioned that she was against routine procedural problems as on textbooks, therefore she created contextual, challenging, and visualized problems. The problems included visual models of fractions where the corresponding fractions were asked, word problems, and one procedural problem about the addition of fractions. She constructed questions which included multiple representations to be used for evaluating the objectives about the fractions subject. Likewise, P6 visually supported the questions on Kahoot by integrating pictures of prisms and asking the name of the solid presented in the geometric Figure 5.2.

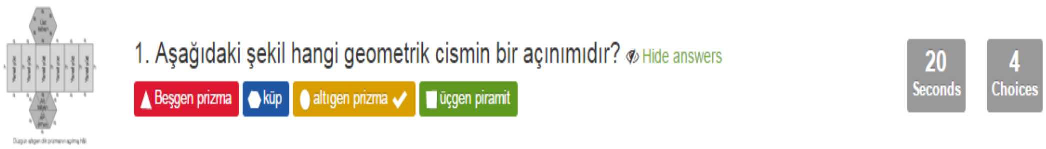


Figure 5.2 P6's two dimensional representation of a hexagonal prism

She used "adding a photo" feature in all of the questions in her quiz. The questions referred to these pictures.

P2 preferred Kahoot for the end-of-course assessment. P2 prepared questions that were about construction of geometrical shapes instead of computational and routine questions. Specifically, the questions asked for determining the height with respect to different bases in a paralellogram. She emphasized that she observed in collaborating middle school and her private courses with middle school students that students struggled while determining the height of a geometrical shape. She added that this resulted in misconception about measuring the area of geometrical shapes.

Participants commented about the physical aspects of the online assessment programs and how teachers should use them pedagogically. P5 expressed that she was fond of online assessment programs and she considered them useful in all mathematics subjects for middle school level. She especially suggested the use of Kahoot for motivating students to participate.

> I think online assessment systems are very useful. They are applicable not only for fractions but for all subjects in mathematics. (…) There is a competition environment in Kahoot. That attracted all of us. One reason is that we see our progress immediately in the feedback. Secondly, everyone tries to answer fast to

compete. This motivated us to participate. (P5)

Although P3 implemented end-of-course assessment through Socrative, she mentioned in the interview that she favored Kahoot over Socrative for being more enjoyable for its sound feature. Considering P3's quiz, P8 criticized the lack of feedback to open-ended questions and suggested that P3 should have guided discussions about the false answers. P8 emphasized that the size of the shapes in the questions and the time provided for each question were important issues when utilizing Kahoot in assessment. P8 provided instant feedback to her peers' answers. Considering P5's quiz, P6 mentioned that the difficulty order of the questions was not determined and most of the peers criticized that the time given for solving the questions was too short.

5.3.2.2 Planning and Design and Enactment Domain

Participants in the Mostly Infusive Application group, with exception of P3 and P9, progressed at level 3 in planning and design domain and enactment domain. P3 and P9 progressed at level 2 in enactment domain. The participants used appropriate technology and digital representations to explicitly present mathematics content, to encourage mathematical thinking, to promote students' learning through investigating mathematical concepts, and to enhance instructional effectiveness.

P3 planned and designed a course about properties of triangles and rectangles subject in the 5th grade. She initiated the course with an origami activity to construct a cube. The aim of the activity was to enable students to identify the relationship between square, rectangle, triangle, and the types of these geometrical figures. The triangle types were pronounced in each folding step. P3 considered using a cube-construction video from YouTube video sharing channel to support students' mathematical investigation by the demonstration of the origami activity and to support her instruction visually. She stopped the video several times to discuss about geometrical shapes occurred on the origami paper. In these discussions, she referred to the image of different steps of the origami activity from the video displayed on the screen. As a pedagogical aspect of selecting and using appropriate technology strategically, she mentioned that the video should be used in mute mode since the videos she searched did not include instructions with proper mathematical language. P11 mentioned in the peer-assessment form that using the video to support the origami activity would be effective when applied to 5th graders. P6 and P7 mentioned that P3's student-centered origami activity was effective for providing their active participation. Similarly, P5 designed and implemented an origami activity to construct a cube where she managed students to work in groups. The subject was addition of fractions with equal and unequal denominators in the 5th grade level. Meanwhile, P5 featured a video from YouTube online video channel at the time of the activity with the aims similar to P3's aims. The video was demonstrating the steps of the origami activity. In the activity, the origami cube was formed by 6 pieces of folded paper with different colors. These pieces come together and form the sides of the cube. Each side was formed by 4 different pieces. P5 asked the fraction of each color in one side. For instance, she asked the fraction of yellow in all of the sides of the cube. Then, she guided her peers to write other questions about addition of fractions according to different colors that form the cube. The discussion proceeded based on the video. These were student-centered construction activities including multiple representations that were conducted in a collaborative environment.

Participants in this group constructed technology-supported instructions based on students' prior knowledge and built a base for related concepts through strategic uses of technology. For instance, P3 associated the basic properties of triangles and rectangles subject with several other mathematical concepts such as angles and fractions through the activity. She also mentioned in the interview that she considered the importance of prior knowledge and association between concepts. Supporting this, she expressed that she designed the course to constitute a base for the following subject which was identification of three dimensional geometric solids. She used a video from YouTube and planned to utilize a Smart Board to serve these aims.

P3 and P8 planned to use Smart Board technology to explicitly present content, promote mathematical thinking, and provide students the opportunity to construct their own knowledge. P8 planned to use isometric background on Smart Board by guiding students to reach the perimeter and area formula of a square. To achieve this, she planned to guide students to draw squares with different sizes on the Smart Board, calculate the perimeter and area for each of them by making use of isometric background, and then interpret the general rule for perimeter and area collaboratively through brainstorming. P8 stated that she learned how to use a Smart Board in the TUME course in the middle school visit for learning about Smart Boards and wanted to utilize it in the collaborating school since then. She expressed that there were Smart Boards in some classes in the collaborating middle school and teachers were not able to use them. She initiated its use in the school at the times she was there, once in every week through the semester. P8 instructed the same course in the collaborating middle school in the context of Teaching Experience course. She expressed in the interview that *"it is an effective platform that enhanced [students'] learning by experimenting, visualizing, and manipulating. This helped to construct their own mathematical knowledge."* However, P8 could not implement the lesson plan exactly in the micro-teaching since Smart Board was not present in the classroom at the faculty. P8 criticized her own instruction and stated that she would have supported her instruction with GeoGebra to construct a square. All of the participants reported on the peer assessment forms that P8 should have constructed a square and guide students to reach its perimeter and area formula on GeoGebra.

Similar to P8, P3 designed a plan where Smart Board was the main tool for teaching the properties of triangles and rectangles through construction in a student-centered instruction. P2 and P10 expressed that P3's plan to utilize a Smart Board would be beneficial in terms of accurate and visual representation of the content. P2, P7, and P11 suggested P3 to utilize additional technologies since there are many online manipulative and software that would enrich the geometry content of the implementation. P3 responded to these suggestions by expressing that *"Firstly, I planned to use GeoGebra. The students were using it [GeoGebra]. But, I don't think it is appropriate for 5th grade students since they cannot use it easily. That is why I changed my decision."* P1, P6, and P10 suggested utilization of

GeoGebra, too. P6 emphasized that the course objectives were completely aligned with the affordances of the tool. Among the course objectives, P6 especially mentioned drawing and identifying basic elements of the quadrilaterals in a student-centered environment to provide students construct, explore, and associate the geometrical shapes.

P6 used cardboards to show the triangular and hexagonal prisms in two dimensional forms. In the interview, P6 stated that she would have searched and used virtual reality about geometric shapes to present the three dimensional versions next time she instructs this subject. P6 also added that she would have used GeoGebra to construct the geometric solids. According to P5 and P10, the subject was applicable to be presented using GeoGebra for the three dimensional views and parts of geometric solids. P6 showed triangular and hexagonal prisms on a Powerpoint presentation and asked questions about their properties. P1 criticized the technology use as teacher-centered and suggested the use of a website with manipulatives about three dimensional figures in a student-centered environment.

P2 presented a poster showing the area formulas of a rectangle, parallelogram, a trapezoid, triangles with three types of angles, and a circle. On the poster, the heights of seven geometric shapes were drawn. She emphasized that the most essential concept to be emphasized was the height concept and demonstrating heights on each geometric shape was an important goal. Then, she drew the heights of the shapes on the poster with students and discussed the area measurement altogether. The printed version of the poster was hanged on the bulletin board. She stated that the digital version of the poster should be presented on Smart Board. P4 stated in the peer-assessment form that the design of the poster was aligned with students' level and can motivate them to learn the subject. In addition, P8, P9, and P11 emphasized that posters visually enriched the instruction where geometrical shapes and height were represented visually in a way that facilitated mathematics learning. P11 highlighted the effectiveness of forming relationship via posters that consisted relational information about parallelogram and prior knowledge about other geometrical shapes. P8, P9, and P11 suggested supporting the implementation with other technologies to create a more effective and fruitful instruction. In this respect, P9 especially suggested the use of GeoGebra. P2 mentioned in the interview that she was eager to use GeoGebra in her implementation about the area of a parallelogram. However, she did not plan or conduct the micro-teaching likewise. P1, P4, and P9 mentioned the need for enhancing active student participation in the implementation. P4 added on this by suggesting learners' own construction of heights of the geometric shapes through utilizing technology. She suggested this both in finding the area formulas and in the assessment part.

Visualization was the most common issue that participants criticized in the peer-assessment forms and interviews. Participants made specific suggestions about how to enhance instructions via appropriate technologies in terms of visualization of mathematical concepts. For instance, P3 made some criticisms on her micro-teaching when she watched the video in the interview as *"I see now. I should have used materials with appropriate technology for visualization. Visualization of concepts definitely enhance students' understanding."* P3 expressed in the micro-teaching that she planned to utilize Smart Board to serve this aim. P2 and P10 expressed that P3's plan to utilize a Smart Board would be beneficial in terms of accurate and visual representation of the content. P3 expressed in the interview that next time she instructs 5^{th} graders about properties of geometric shapes, she would present pictures from Pinterest to provide visual examples of the geometric shapes. Likewise, P9 expressed in the peer-assessment form that P3 should have used online manipulatives to support visualization. She expressed that the origami video P3 showed in the activity enhanced the instruction visually which also encouraged and supported peers' participation to the activity.

Another micro-teaching that was criticized in terms of visualization was P5's micro-teaching about addition of fractions referring to the 5^{th} grade. In the peer-assessment form, P9 suggested the use of online games and manipulatives about fractions since the level of students was inclined to playing games. P1 and P6 criticized that the subject was inadequately supported with technology although there were a plenty of options for enhancing this instruction about fraction subject. P1 stated that she used Pinterest when she instructed this subject in the collaborating middle school and offered P5 to use especially Pinterest to search for several materials and to create a poster that supports visual representation of fractions in different models. P8 pointed the need for visualization in the instruction, too. To remedy this, P10 suggested using Smart Board features to draw different wholes and show pieces to visualize fractions.

P6 was favored in terms of visualization by her peers. Her microteaching was about solids in the 8th grade level. She started the implementation by presenting photographs of design objects that she downloaded from Pinterest. These objects were formed by geometrical shapes found in daily life such as triangles, hexagonal prisms, and spheres. P4 favored P6's utilization of Powerpoint for enhancing instruction in crowded classrooms. P3 favored the visualization of the subject content through presenting daily life objects. In addition, P6 prepared a worksheet by combining the tasks which she also found from Pinterest.

The tasks included nets of some geometric solids leading students to find the properties of solids. P6 stated in the interview that the subject was abstract and visualization was necessary to concretize it. She suggested utilization of virtual reality and GeoGebra to provide investigation of the solids.

5.3.2.3 Summary of TPACK-P Progress

The performance of the participants in this group in three domains of TPACK-P included considerably effective technology-enhanced applications. However, the plans and implementations could have been improved at some points. To start with, some prior assessment examples existed in the implementations. There were three technology integrations to identify prior knowledge, misunderstandings, learning styles, and learning needs. Classroom discussions were held relying on the poster prepared by Powerpoint or Glogster to build relationship with the previous knowledge linked with the new one (P2), the Powerpoint presentation of geometric figures in daily life selected from Pinterest (P6) and an origami video on YouTube (P3). Then, the instructions were organized based on the answers of the students. However, technologies were indirectly used in these assessments. Other three participants (P5, P8, and P9) assessed students' prior knowledge and learning needs verbally but they did not facilitate any technologies in this step.

All of the participants in the Mostly Infusive Application group conducted post-assessments by using online assessment programs to assess and evaluate mathematical knowledge and to identify and support diverse student-learning. There were different problem types including different representations of the mathematics subjects. In addition, the participants formed discussion environments and evaluated the assessment results relying on the detailed feedback provided by the assessment programs. However, there were no attempts of conducting assessment to determine whether the instruction was implemented well. Only one participant (P9) mentioned in the interview that technology can also be used to assess the quality of the instruction.

Participants considered some pedagogical aspects in the construction of quiz items and application of the quizzes. They guided and managed interactive classroom discussions by asking leading and interpretive questions relying on Powerpoint presentation, YouTube video or online assessment programs. All of them were aware of the importance of identifying prior knowledge connected with the new subject and determining learning needs and misconceptions. All of the participants used the affordances of the online assessment programs while preparing and conducting the quizzes. The questions in the quizzes included construction of height in geometrical shapes (P2), word problems (P6), different types of questions (P3 and P6), and various representations (P5 and P8). They constructed multiple-choice, true-false, and open-ended questions and added photos to some of the questions. They managed the settings of the quizzes such as the size of the pictures in the questions, the difficulty order of the questions, the time given for solving each question, and the feedback provided by the program which is written by the teacher while preparing the quiz.

Participants in the Mostly Infusive Application group planned and enacted technology-assisted courses which included student-centered activities. The activities were conducted in a collaborative environment to promote comprehension and aimed to enhance active-participation. In addition, technology use aimed at promoting students' own construction of knowledge. For instance, P8 planned to use isometric background on a Smart Board to provide a dynamic setting where students can construct different squares, calculate perimeter and area of them, and conclude to general rules for finding perimeter and area of a square. P6 planned teaching prisms by using virtual reality programs and GeoGebra to provide students construct prisms and investigate their properties.

Participants criticized their plans and micro-teachings afterwards in terms of lack of technology-support. They suggested the use of GeoGebra dynamic environment for teaching and learning of subjects such as perimeter and area of a square, properties of quadrilaterals, and prisms through construction. Pinterest was facilitated by all participants to search up-to-date materials and designs such as activity ideas, posters, or pictures about any mathematics subject. Materials and pictures from Pinterest, YouTube videos, online games, online manipulatives, and Powerpoint presentation were commonly mentioned by the participants to enhance visualization of the concepts, to concretize abstract concepts, and to promote diverse student-learning.

Planning and design performances of the participants in this group were relatively better than their enactment performances. Their plans and suggestions about integration of appropriate technologies such as Smart Board and GeoGebra were aimed at facilitating learning through investigating and constructing concepts in a student-centered environment. Although participants mentioned several technologies that would enhance their instructions, they recognized the need for and effectiveness of integrating these technologies after they watched their micro-teaching videos and read peer-reflection forms. Therefore, the micro-teachings did not include all the technologies they suggested.

5.3.3 Group 3: Mostly Reflective Application

Participants included in this group were P1 and P11. Their overall TPACK-P performances were aligned with level 3 and 4 according to the analysis of the data obtained during and at the end of the course. Participants' TPACK-P levels in three domains were given in Table 5.8.

Table 5.8

TPACK-P Levels of the Participants in Mostly Reflective Application Group

Levels	Assessment	Planning and Design	Enactment
4: Reflective Application	P11	P1, P11	P1, P11
3: Infusive Application	P1		
2: Simple Adoption			
1: Lack of Use			

As mentioned earlier in this chapter, these participants progressed at level 1 in the three domains of TPACK-P at the beginning of the TUME course. Hence, compared to the beginning of the course, there was a remarkable development in their TPACK-P. Their performances were consistent with the indicators of level 4 in all domains in exception of P1's performance at level 3 in assessment domain. The participants in this group were able to select and adapt appropriate technologies to evaluate students' learning styles and difficulties, prior knowledge, and mathematics knowledge before, through, and after instruction. They designed and implemented technology-supported student-centered instructions in which functions of technologies were utilized efficiently and strategically to enhance students' exploration of mathematical concepts and construction of their knowledge. Technologies were meaningfully and purposefully integrated to curriculum goals to improve instructional efficiency. In this section, participants' progresses in the three domains of TPACK-P were explained aligned with the principles of TPACK-P framework and examples were provided.

5.3.3.1 Assessment Domain

The PMTs in the Mostly Reflective Application group utilized technology-assisted assessments for several educational aims. These were exemplified below with instances from their lesson plans, classroom implementations, and interviews. To start with, P11 considered students' prior knowledge about the properties of a parallelogram. She asked questions to identify prior knowledge through an activity on GeoGebra and the answers formed the base of the construction of a parallelogram on GeoGebra. She managed the instruction accordingly. Besides, in the interview, P1 suggested the use of technological assessments to provide teachers with the detailed information about students' needs. She expressed as follows:

> It is a challenging task [for teachers] to identify what students' misunderstandings and needs are. I know some of these from my observations in the individual private courses. It is really very hard to identify and compensate the misconceptions. Because, when you ask the student, he does not know what he knows wrong and what he needs to know. Simply asking students and relying on their statements is an unreliable way to identify their [students'] prior knowledge and misconceptions. It is your [teacher's] job to reveal it [misconceptions and learning needs]. Technology will be very helpful for teachers in this regard. (P1)

She also mentioned that middle school students frequently confronted misconceptions about height concept in geometry and therefore, she focused on it through her instruction. However, she did not utilize technology to serve prior assessment purpose. She expressed the reason of this in the interview as:

> I did not utilize technology to identify prior knowledge or learning needs in the beginning of the course [micro-teaching]. Because, I already designed my lesson plan considering the misconceptions that middle school students faced which I had known from my individual private courses with them [students]. (P1)

P1 and P11 preferred Socrative online assessment program to conduct quizzes at the end of their micro-teachings. P11 implied that she used Socrative in post-assessment both to assess students' mathematical knowledge and for evaluation of her teaching. She also criticized the assessments in her peers' micro-teachings from this point of view. For instance, she expressed that P3's quiz on Socrative served for both of these aims. P1 favored the use of technology-integrated assessments for both students' and teachers' benefit. She expressed that online assessment programs inform about both individual student performance and efficiency of the instruction. Her view was as follows.

> Knowing about who performed how can be useful. This would be better for me as a teacher. It can help me to see to what extent my instruction influenced students. This can provide a variety of feedback both for children in terms of pedagogical needs and the teacher in terms of how much she achieved the goals and reached to the children, how much she was understandable, or what her deficiencies were. (P1)

P11 also stated that Socrative provided learners feedback that helps to determine their learning needs. The online assessment programs provided detailed results for each participant. P11 guided a discussion about the wrong answers given by the peers that was presented in the performance report of Socrative. P1 expressed that Kahoot and other online assessment programs can be used to track students’ performance and present the assessment reports to the parents.

Participants asserted pedagogical principles for assessing through online assessment programs. For P1’s quiz on Socrative, participants mentioned the quality of the problems. Moreover, they expressed at the end of the micro-teaching that P1 fitted the questions and answer options to Socrative strategically. P1 instructed the micro-teaching subject in the collaborating school, too. She mentioned that some of the middle school students in the collaborating school could not understand and solve questions related with measurement of height and area of the triangle subject. She expressed that, this might have been resulted from the lack of knowledge or hesitation for giving wrong answers. She stated that “*if I was able to use Socrative in the assessment part, all students would have actively participated willingly. In addition, they would have participated with no reason for hesitation since they have the chance to use nicknames when connecting [to the assessment program]*.” Peers stated that they intended to draw on the geometrical shapes in P11’s quiz but they could not. P11 expressed in the interview that she agreed with this criticism for the reason that geometry is a visual subject needing construction on the geometrical shapes. P11 pointed to the implementation of the technology-integrated assessment by stating that as follows:

> The time assigned to each question should be attentively determined [by the teacher]. In addition, the questions [in the assessment] can also be given to students on a paper to provide them for making calculations or drawings on the figures with pencil. They will both see the question on Socrative and solve it on the paper. (P11)

To sum up, participants did not implement all of the planned assessments in the micro-teachings. However, they presented ideas reflecting skillful and strategic uses of technologies in their lesson plans and/or interviews for assessment and evaluation purposes. P11 identified students’ prior knowledge which was knowledge about properties of geometrical shapes to link with the new concept which was the properties and area of a parallelogram. She utilized an activity on

GeoGebra for identifying students' needs about the concepts and managed the instruction accordingly. P1 emphasized the importance of identifying students' misconceptions prior to the course through online assessment programs. P1 and P11 used Socrative for end-of-course assessments. P1 favored the program for enhancing active participation, informing students about their individual performance, and informing teachers about the effectiveness of the instruction. P1 and P11 both favored Socrative's report about students' as they mentioned in the interviews that *"the reports can be used to evaluate students' performance and can inform both teachers and parents"* (P1) and *"teachers should give feedback [to the students] about the wrong answers relying on the performance report [provided by the online assessment programs]"* (P11).

5.3.3.2 Planning and Design Domain and Enactment Domain

Participants in the Mostly Reflective Application group planned and implemented courses about geometry and measurement subjects. P1 designed a lesson plan about height and area of a triangle referring to 6^{th} grade. She considered middle school students' misconceptions about height concept in geometry when designing the lesson plan. One misconception was about students' assumption that height should always be inside a triangle. To remedy this, she demonstrated on GeoGebra that the place of height changes when the measure of the angle changes from acute to obtuse. As the second misconception, she considered the misunderstood relationship between height and base. She presented three types of triangles with cardboards. These were acute-angled triangle, right-angled triangle, and obtuse-angled triangle. Then, P1 utilized GeoGebra to demonstrate the relationship between height and base in these three types of triangles. She constructed a triangle and generated different angled triangles by sliding vertex A and showed the change in the place of height as shown in Figure 5.3.

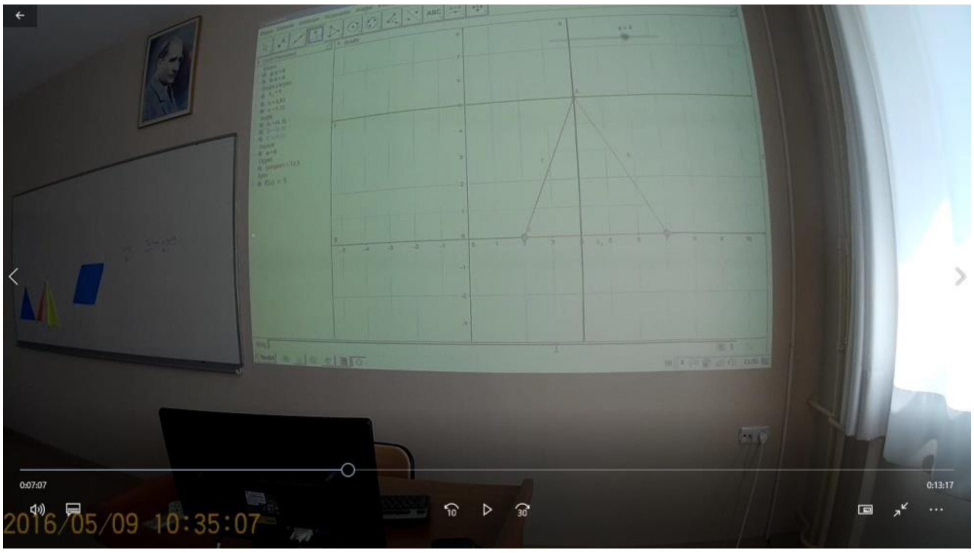


Figure 5.3 Construction of a triangle and height

Firstly, she wrote a function, *f(x)=5* on the algebra window. Then, she created a slider; fixed it between -10 and +10; and created point *A* connected to this slider. This point was moving along the *f(x)=5* line. As a second construction, she drew triangle *ABC*. Point *A* was situated as the vertex of the triangle. Then, she drew a line from point *A* to side *BC*. She intended to draw the height. Therefore, she checked the measure of the angle to see whether the line was perpendicular to side *BC*. In the third step, the area of triangle ABC was found from area calculation command. After the construction ended, she moved vertex *A* along the *f(x)=5* line by using the slider while showing that the measure of the area stayed the same. The measure of angle *ABC* changed depending on the movement of vertex *A*. Hence, the heights of acute-angled, right-angled, and obtuse-angled triangle were demonstrated dynamically. It was seen that measure of the height stayed the same. She also proved that the area of the triangle did not change as the length of height stayed the same. She managed this construction process by addressing questions to the class in every step.

P1 mentioned in the self-assessment form that utilizing GeoGebra was one of the strengths of her implementation. She mentioned her main aim in utilizing this technology as demonstrating proof through concretization and visualization:

I used GeoGebra which is an effective program in concretizing the relationship

> between theorem and proof in mathematics. Yet, many concepts can be concretized through using only GeoGebra. In my implementation, I showed that although the angle of a triangle and position of the height changes, area of the triangle stays constant. (P1)

P1 asserted several specific reasons in the interview about why she utilized GeoGebra to overcome or hinder the misunderstandings about the subject. Firstly, she explained that this was available by the representations and dynamicity that GeoGebra provided. In the dynamic *ABC* triangle on GeoGebra, she showed different versions of a right-angled triangle mentioning that teachers are used to show one version of a right-angled triangle in traditional classrooms. Secondly, P1 stated in the interview that geometry develops spatial intelligence and GeoGebra supports this development dynamically by mentioning her micro-teaching application. P1 referred to the grid background of the GeoGebra as a functioning feature for teaching geometry subjects. Thirdly, she referred to the role of GeoGebra for exploring and rationalizing mathematics. Fourthly, among the capabilities of GeoGebra, P1 mentioned its role in associating concepts. She mentioned that teachers start a subject without relating with the previous knowledge which results in students' construction of disconnected knowledge. She exemplified this by mentioning the relationship between rectangle and square. She stated that GeoGebra served to build connection between concepts of height, angle, base, and area of a triangle.

P1 taught this subject in the collaborating middle school in 6^{th} grade classroom. She used cardboards as there was no computer in the classroom for using GeoGebra. In the interview, she specified the affordances of GeoGebra by expressing her experience with a 6^{th} grade student in the collaborating school when she was teaching the same subject with the micro-teaching. She stated that the student asked the area of a triangle when it was divided into four equal triangles. P1 expressed that she used cardboards to show a rectangle to answer the question. However, she complained for the inadequacy of the cardboards to present what she intended. She stated that she would have preferred to demonstrate on GeoGebra if there was a computer or a Smart Board in the classroom. She continued as follows:

> Besides the visual representation advantage, GeoGebra provides what cardboards

> cannot serve. That is, GeoGebra calculates the measure of the area simultaneously when I move the vertex of the triangle. This was impossible to be accomplished in my instruction in the collaborating middle school. I needed GeoGebra very much then [in the collaborating school]. Students cannot comprehend that measures of height and area stays the same when the place of vertex moves along a line parallel to the base of a triangle. This can easily be understood when GeoGebra is utilized. (P1)

P11 designed a plan about the parallelogram which covered three objectives from the 7th grade and one objective from the 8th grade. These objectives were about the length of the sides, the angles, the diagonals, the angles between the diagonals, and the area. Similar to P1, she utilized GeoGebra in teaching the first three objectives. She constructed the parallelogram shown in Figure 6 and she referred to its properties throughout the construction.

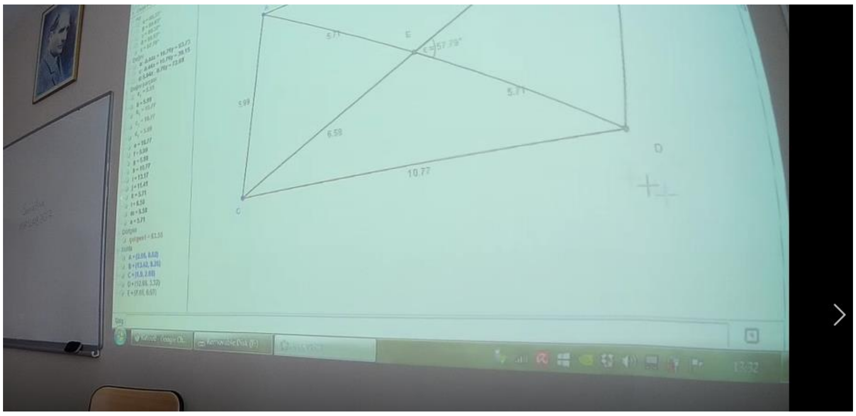


Figure 5.4 Parallelogram construction on GeoGebra

After the construction, she divided the parallelogram into two equal triangles. She replaced one triangle and formed a rectangle. She showed the angles between the diagonals of the parallelogram as presented in Figure 5.4. She referred to the misconception that the measure of this angle is generally assumed to be 90 degrees. Moreover, by dragging the figure from one corner, it was seen on the left column on the GeoGebra screen that the sum of the measures of opposite angles was constant and the measure of the opposite angles were always equal. She also demonstrated that the lengths of the diagonals of a parallelogram are not equal but they always cut each other into two equal pieces from the center.

When P11 was asked to explain the role of the technologies she utilized in her micro-teaching, she told about her implementation in the collaborating middle school in the context of her Teaching Experience course. She mentioned that in the collaborating school, the students tended to memorize the properties of geometry subjects.

> I instructed about the sides, angles, and diagonals of a parallelogram in the middle school. It was superficial. Students tend to memorize. For example, they directly say that the angle between the diagonals (of a parallelogram) is 90 degrees. They confuse parallelogram with rhombus. Some of them think that the angles (of a parallelogram) are 90 degrees. (P11)

P11 also mentioned that it is effective to overcome the misconceptions since GeoGebra provides to build a relationship between elements of geometrical shapes through construction. She mentioned another experience from the collaborating middle school as follows.

> They (students) don't know where it comes from, why the area is like that, without any visualization, they memorize the rules like a linguistic course. There are students who can not differentiate a parallelogram from a rectangle visually. But they can accurately count their properties. Then, when a question is asked, they can assign the values on the area formula but they confuse the properties. (P11)

The fourth objective was not addressed through GeoGebra. P11 stated that she rather used cardboards since it was difficult for her to demonstrate on GeoGebra. As she expressed in the interview, she searched about the construction of area of a parallelogram on GeoGebra and that she watched videos about it. However, she considered that demonstration of area of a parallelogram on GeoGebra was not appropriate for students' learning styles and levels.

P1 and P11 utilized technology by effective interaction with peers through directing guiding questions continuously. They performed exemplary student-centered technology-integrated instructions. They, as the teachers, used the computer by themselves due to the conditions in the faculty classroom that peers did not have computers. However, they both stated in the interviews that they would implement the same courses in a computer laboratory. P1 expressed that this would provide the middle school students with the opportunity to individually explore the relationship between heights, areas, and angles of the triangles. In addition, P1 pointed to the importance of students' own construction of triangles and heights for their own learning:

> If they draw by themselves, they can recognize the elements of a triangle in detail which would result in true determination and construction of height belonging to a base. (P1)

P11 mentioned the need for student-centered instruction as follows.

> If I teach to 7th grades, I would ask students to use GeoGebra on a Smart Board to enable them explore the angles, sides, and other properties of a parallelogram respectively. They would learn better. (P11)

P1 explained how he/she used GeoGebra technically well at the end of the micro-teaching session. P11 considered the technical issues about Socrative and GeoGebra whether she would be able to operate it in the instruction without having any technical problems. Moreover, she considered the time management for construction on GeoGebra. Therefore, she expressed that she made rehearsals more than once prior to the micro-teaching. P11 expressed in the interviews that she was introduced with GeoGebra in another undergraduate course and developed her GeoGebra using skills on her own since then. She stated that she considered GeoGebra easy-to-use for teachers and very functional in teaching geometry subjects that was why she used it as the main tool in her micro-teaching professionally.

5.3.3.3 Summary of TPACK-P Progress

Participants in the Mostly Reflective Application group presented ideas reflecting skillful and strategic uses of technologies for assessment and evaluation in their lesson plans and interviews. P11 identified students' prior knowledge which was knowledge about properties of geometrical shapes to link with the new concept which was the properties and area of a parallelogram. She utilized an activity on GeoGebra for identifying students' needs about the concepts and managed the instruction accordingly. P1 emphasized the importance of identifying students' misconceptions through online assessment programs. P1 and P11 integrated Socrative for end-of-course assessments. P1 favored the program for enhancing active participation, informing students about their individual performance, and informing teachers about the effectiveness of the instruction. P1 and P11 both favored Socrative's report about students' performance. P1 mentioned that the reports can be used to evaluate students' performance and can inform both teachers and parents. P11 suggested teachers to give feedback about the wrong answers relying on the performance report.

Participants utilized technology to enhance students' learning, to facilitate both teacher's and students' exploration, and construction of mathematical knowledge with strategic, skillful, purposeful, and meaningful uses of technology. Technology integration improved their instructional effectiveness. They redesigned mathematics objectives in the curriculum to integrate technology meaningfully. The implementations referred to the learning objectives in the curriculum but they were redesigned in a way that was completely different than traditional content. The objectives about a concept were covered all together rather than separately. Moreover, participants presented the relationship between them through construction and representations. The measurements were related with the positions of the geometrical figures. The visual and numeric representations were shown simultaneously on GeoGebra.

Participants designed the courses considering middle school students' learning needs that they identified in the collaborating middle school. According to their experiences, they considered GeoGebra as an appropriate and effective technology to explicitly represent properties and area of a triangle and a parallelogram. They related the representations with each other such as the place of the height on the triangle and the measure of the angle appeared on the algebra screen. They mentioned the importance of student-centered strategies to construct both their own learning and students' learning and to facilitate students' exploration of mathematical phenomena. Their intention for future courses was that students learn mathematics through constructing and manipulating on GeoGebra. They were comfortable with using GeoGebra and all of the technologies included in the TUME course. They took advantage of the powerful capabilities that were specific to each technology. For instance, P1's dynamic construction of a triangle to demonstrate the relationship between angles, sides, and kinds of triangles was an effective implication of transformation of the subject matter through technology.

5.4 Summary of the Findings

The present study aimed at developing PMTs' TPACK-P through an undergraduate course and then identifying the development of their TPACK-P proficiency levels. Their initial and final TPACK-P proficiency levels were investigated and determined to reveal the influence of the TUME course. Their TPACK-P proficiency levels were determined with respect to the three pedagogical domains identified in the TPACK-P framework which were Assessment domain, Planning and Design domain, and Enactment domain. Knowledge about and practices of technology integration were exemplified by detailed narration in this chapter.

Participants' responses to the two questionnaires and the content of the technology-integrated lesson plans were investigated to identify their initial TPACK-P levels for two domains, the assessment domain and the planning and design domain. Participants did not consider technology as a teacher knowledge type such as pedagogical knowledge and content knowledge since here was no emphasis on technological knowledge among the answers participants provided for the two questions in The Views about Teaching Profession Questionnaire. Answers provided for Technology Usage Questionnaire revealed 18 types of technologies that participants knew about and used before. Although there were a broad range of technologies that they were aware of and that they had used for several educational aims, they did not integrate these technologies in their lesson plans. Six participants among 11 integrated technologies to their initial lesson plans. However, the technologies were incompatible with the mathematical content. Moreover, the pedagogical strategies matched with the selected technologies were not mentioned. According to these findings, it was decided that all participants were at level 1 in the Planning and Design domain of TPACK-P. In addition, there was no participant who mentioned technology use for assessment and evaluation purposes neither in the lesson plans nor in the questionnaires. Therefore, all participants were considered to be at level 1 in the Assessment domain.

Participants' TPACK-P proficiency levels at the end of the TUME course were determined according to their second lesson plans, micro-teaching videos where they enacted the course in their lesson plans, the peer- and self-assessment forms filled by their peers and by themselves considering their micro-teaching, and the individual interviews after they completed all of the TUME course requirements. Participants' TPACK-P levels differ in three domains. Considering the proficiency levels for each domain, participants were clustered in three groups: (1) Mostly Simple Adoption group, (2) Mostly Infusive Application group, and (3) Mostly Reflective Application group, corresponding to TPACK-P proficiency levels of 2, 3, and 4, respectively.

The participants in the Mostly Simple Adoption group tended to utilize technology to assess mathematics learning by providing repeated practices in a motivating platform to enhance participation. They basically considered using online assessment programs for their physical properties and being user-friendly both for students and teachers. All of them prepared comprehensive questions and were able to use different question types that the programs offered. They particularly emphasized technology integration in their plans and interviews to present mathematics content digitally for providing visualization, summarizing the subject, and increasing student motivation towards learning mathematics. Their views about integrating technology were teacher-centered as well as their plans and micro-teaching implementations.

The performance of the participants in the Mostly Infusive Application group in three domains of TPACK-P included considerably effective technology-enhanced applications. Three participants utilized technology for pre-assessment to identify prior knowledge, misunderstandings, learning styles, and learning needs and to build relationship between previous knowledge and the new knowledge through classroom discussion. All of the participants in the Mostly Infusive Application group conducted post-assessments by using online assessment programs to assess and evaluate mathematical knowledge and to identify and support diverse student-learning. There were different problem types including different representations of the mathematics subjects. In addition, the participants formed discussion environments and evaluated the assessment results relying on the detailed feedback provided by the assessment programs. They considered several pedagogical aspects while utilizing technologies for post-assessment purposes. All of them were aware of the importance of identifying prior knowledge connected with the new subject and determining learning needs and misconceptions. All of the participants used the affordances of the online assessment programs while preparing and conducting the quizzes. However, there were no attempts of assessment to determine whether the instruction was implemented well. They planned and enacted technology-assisted courses which included student-centered activities. The activities were conducted in a collaborative environment to promote comprehension and aimed to enhance active-participation. In addition, technology use aimed at promoting students' own construction of knowledge. Planning and design performances of the participants in this group were relatively better than their enactment performances.

The participants in the Mostly Reflective Application group were able to select and adapt appropriate technologies to evaluate students' learning styles and difficulties, prior knowledge, and mathematics knowledge before, through, and after instruction. They designed and implemented technology-supported student-centered instructions in which functions of technologies were utilized efficiently and strategically to enhance students' exploration of mathematical concepts and construction of their knowledge. Technologies were meaningfully and purposefully integrated to curriculum goals to improve instructional efficiency. Participants' utilized technology to enhance students' learning, to facilitate both teacher's and students' exploration and construction of mathematical knowledge with strategic, skillful, purposeful, and meaningful uses of technology. Technology integration improved their instructional effectiveness. They redesigned mathematics objectives in the curriculum to integrate technology meaningfully. The implementations referred to the learning objectives in the curriculum but they were redesigned in a way that was completely different than traditional content. The objectives about a concept were covered all together rather than separately. Moreover, participants presented the relationship between them through construction and representations. The measurements were related with the positions of the geometrical figures.

CHAPTER 6

DISCUSSION

The aim of the present study was to enhance and investigate pre-service middle school mathematics teachers' (PMTs') Technological Pedagogical Content Knowledge - Practical (TPACK-P) development through the undergraduate course Technology Use in Mathematics Education (TUME). The theoretical basis of the present study was grounded on the practice-based and content-specific nature of TPACK. Thus, TPACK-P framework was used as a practice-based framework to develop and investigate PMTs' technology-integration skills through an undergraduate course which focused on effective utilization of various technologies in relation with pedagogical strategies in teaching middle school mathematics content. The results showed that the TUME course empowered PMTs' technology integration proficiencies with respect to TPACK-P framework. PMTs' beginning TPACK-P was detected at level 1 which is the Lack of Use Level. PMTs' progresses revealed TPACK-P development at the end of the TUME course. Hence, their TPACK-P levels increased from level 1 to higher levels in all three domains.

PMTs' TPACK-P proficiencies at the end of the TUME course were mainly reported with respect to the indicators in the TPACK-P framework in the previous chapter. PMTs' TPACK-P developments were reported in three groups which were Mostly Simple Adoption Group, Mostly Infusive Application Group, and Mostly Reflective Application Group corresponding to levels 2, 3, and 4, respectively. The group members showed similar knowledge and behaviors in Assessment domain, Planning and Design domain, and Enactment domain as proposed in TPACK-P framework (i.e., Jen et al., 2016). PMTs' technology integration revealed their TPACK-P in various extends and these aspects were discussed in comparison with the relevant literature in this section. Then, implications for practice and recommendations for further studies were provided in the light of the findings of the study.

Stating the definitions of TPACK-P levels at this point was considered important in order to have a complete understanding of the findings. Teachers' TPACK-P proficiencies were investigated and the components of this knowledge were identified by Yeh, Hsu, Wu, et al. (2014). Then, the features of teachers who possess TPACK-P proficiencies were identified by Yeh, Lin, Hsu, et al. (2015). Finally, the TPACK-P framework was validated and finalized by four levels of teachers' knowledge about and application of TPACK-P and indicators belonging to these levels were identified by Jen et al. (2016). In brief, level 1 (Lack of Use Level) referred to knowing about technologies but not integrating into instruction; level 2 (Simple Adoption Level) referred to integrating technology into instruction to facilitate student learning; level 3 (Infusive Application Level) referred to appropriate selection and meaningful integration of technology to instruction compatible with learning goals and student needs, and supports teachers' instruction; and level 4 (Reflective Application Level), in addition to the purposes in the lower levels, referred to integration of technology in a student-centered learning environment providing reflective thinking and development of creative materials aligned with curriculum (Jen et al., 2016).

6.1 PMTs' TPACK-P Levels at the Beginning of the TUME Course

PMTs' technology acceptance was low that none of them mentioned technological knowledge as teacher knowledge and they hardly mentioned about technology as an educational tool in The Views about Teaching Profession Questionnaire. On the other hand, Technology Usage Questionnaire revealed 18 types of technologies that PMTs knew about and used before, most of which they met in the teacher education program. They mentioned several purposes of their utilization of technology as preparing presentations, posters, puzzles, concept maps, and tests, drawing graphs and geometric shapes, exploring coordinate axis, and making calculations. There was no indication about use of technology for assessment purposes.

Although PMTs had experienced a large spectrum of general and mathematics content-specific technologies previously, five PMTs were not able to prepare a technology-integrated lesson plan in their first lesson plan assignment at the beginning of the TUME course. The rest of the lesson plans included Powerpoint, projector, GeoGebra, and video. PMTs' beginning lesson plans demonstrated technology use for content transfer instead of providing knowledge construction or promoting understanding. They utilized technology as a substitute in their lesson plans. This has been widely discussed among researchers that teachers adapt technologies in transferring the content rather than enhancing student learning (Harris, Mishra, & Koehler, 2009; Sang, Valcke, van Braak, & Tondeur, 2010; So & Kim, 2009). Ozgun-Koca et al. (2010) reported pre-service secondary mathematics teachers' naive use and superficial incorporation of technology at the beginning of the first methods course. Moreover, in their following research, Meagher et al. (2011) identified similar uses of technology in pre-service secondary mathematics teachers' initial lesson plans such as additional tools with no aim for improving the instruction or facilitating students' understanding. The goals PMTs expressed for using the technologies in the present study were concretization and visualization of the mathematics concepts, motivating students, and summarizing the subject. The lesson plans were not detailed about how the technology would be integrated and how it would be implemented in a classroom. The pedagogical strategies were not mentioned either. In addition, there was no technology utilization for assessment purposes such as assessing students' prior knowledge, needs, learning styles, mathematics knowledge, or the effectiveness of the instruction. Moreover, the technology selections in PMTs' initial lesson plans were not related with the mathematics objectives or the mathematics objectives to be addressed in technology utilization were not identified. The learning of the mathematics content was not carried out through the selected technology.

PMTs' beginning TPACK-P levels asserted that they improved capabilities in terms of recognizing and experiencing a variety of technologies in the teacher education program. However, their technology integration knowledge and skills were not adequate for adapting technology to mathematics education. They used technologies in limited facilities although the technologies offered more affordances. Their technology integration experiences were from instructors' use of technology and their own use for preparing assignments and presentations. They indicated that the aim of instructors' technology utilization was to share content. Such technology familiarization of junior and senior PTs were reported elsewhere (i.e., Mouza & Karchmer-Klein, 2013). However, this situation has been a concern raised in the related literature that the courses in teacher education programs, which are merely concerned about the development of technology usage skills, cannot build technology integration skills thereby TPACK, because the technological knowledge presented to PTs is generally isolated (Bakir, 2015; Koehler & Mishra, 2009; Koehler et al., 2007; Mouza & Karchmer-Klein, 2013; Polly et al., 2010; So & Kim, 2009) despite the importance of supporting the development of content-specific knowledge about and application of technology integration (Baran & Canbazoglu-Bilici, 2015; Voogt et al., 2013; Yeh, Hsu, Wu, et al., 2014). Therefore, it might be the case that the teacher education program did not offer sufficient technology integration opportunities for PMTs. The technology emphasis in the program seemed to be rather isolated.

6.2 PMTs' TPACK-P Levels at the End of the TUME Course

The findings showed that all of the PMTs' TPACK-P proficiency levels were increased at the end of the TUME course. While some PMTs performed at the same level in all of the three domains, others' TPACK-P levels differed between the domains. PMTs were clustered according to their TPACK-P levels in three domains. If a PMT progressed at a specific level in at least two domains, then s/he was considered to be at that level for overall TPACK-P. Besides, PMTs' TPACK in using technology in assessment, designing technology-integrated courses, and application of technology-infused instructions were also investigated. Therefore, discussion about PMTs' TPACK-P performances both referred to PMTs' performances between the three groups and the comparison of their performances between three domains in comparison with the results of the related past studies.

6.2.1 PMTs' TPACK-P Levels in Groups

PMTs in the *Mostly Simple Adoption Group* utilized technology mostly for motivation and to increase participation. To serve these aims, technology was incorporated in summarizing the content, presenting example questions, presenting the subject through technology to ease the instruction, and visualizing the content. There were also purposes linked directly with the mathematics content such as using calculators in estimation topic and showing the length measure on GeoGebra. However, their technology integration did not serve for transformation of mathematics subjects to support students' needs and students' construction of mathematics knowledge. Moreover, PMTs utilized only the technologies which fitted to the lesson plans by using them in less potential, although they were aware of the affordances of the technologies and experienced them through the course. They criticized their technology-integrated mathematics course designs in the interviews and expressed that they would add more representations of the content through technology when they would teach the same subject again. This difference might be because PTs tend to have ideas reflected higher level of TPACK than they reflect in their lesson plans (e.g., Meagher et al., 2011). PMTs in this group also emphasized the power of technology in enhancing the instruction and promoting student learning. Appropriate technology selection and cohesiveness with the content (Graham et al., 2012) were successful aspects investigated in PMTs' knowledge about and application of TPACK-P in this group. Apart from their knowledge of TPACK, PMTs in this group could not design and implement technology-integrated lesson plans in student-centered environments. They showed similar characteristics with the teachers in technology transitional group in the study conducted by Yeh, Lin, Hsu, et al. (2015) in terms of considering students' learning difficulties and needs. Yeh, Lin, Hsu, et al. (2015) identified 40 teachers' TPACK-P through interviews. The teachers who were determined as technology transitional teachers stated inflexible utilization of technology. Their knowledge about utilizing technology for assessment purposes was adequate. However, they tended to use traditional assessments. This was also the case for PMTs' instructional planning and design in the present study. They were willing to use technology to assist students' learning and showed efforts to serve this purpose. As indicated in Yeh, Lin, Hsu, et al. (2015), their efforts would have been elaborated by more student-centered uses of technology. These technology transitional teachers were determined to be at level 2 which is Simple Adoption Level (Yeh, Lin, Hsu, et al., 2015) as the PMTs in this group.

In the *Mostly Infusive Application Group,* PMTs demonstrated effective technology-enhanced designs and applications. Some PMTs in this group utilized technology for prior assessment in addition to the end of course assessment applications in the first group. They utilized technology not by merely presenting mathematics content through technology as in the first group but presenting difficult subject content in diverse and efficient ways such as presenting dynamic content through multimedia. Their technology utilization aims were identifying students' learning styles and learning difficulties and assisting learning by utilizing various representations provided by appropriate technologies. PMTs need to develop skills to look beyond most common uses for technologies, reconfigure them for customized pedagogical purposes (Koehler & Mishra, 2009), and repurpose tools for pedagogical purposes (Koehler, et al., 2011). These were evidenced in this group. The technology-infused instructions provided the opportunity to construct knowledge such as, with the support of isometric background on Smart Board. Some of the PMTs considered associating related mathematical concepts and referred to these relations by using the affordances of the technologies. Utilization of technology to build connections between associated concepts was considered as indicator of high level of TPACK in the related studies. For instance, when determining pre-service secondary mathematics teachers' TPACK development, Bowers and Stephens (2011) focused on the attempts for building mathematical relations and probing questions that encourage learners to think from different perspectives in lesson plans and micro-teaching instructions. In this group in the present study, pedagogical strategies were shifted towards student-centered applications in a collaborative environment with the support of technology. For instance, PMTs guided and managed interactive classroom discussions by asking leading and interpretive questions relying on Powerpoint presentation, YouTube video or performance reports of online assessment programs. PMTs mentioned several technologies that would enhance their instructions. However, they recognized the need for and effectiveness of incorporating other technologies after they had watched their micro-teaching videos and had read peer-reflection forms. The peer-assessment practices were reported as having the potential to provide PTs to develop ideas about efficient ways of incorporating technology to enhance their designs (i.e., Agyei & Voogt, 2012; Angeli & Valanides, 2009; Bowers & Stephens, 2011). When compared with their implementations, the knowledge of the PMTs in this group reflected higher level of TPACK-P. Their lesson plans and/or statements in the reflection forms and interviews indicated more effective technology-integration, but their enactments were not at that level, reflecting the previously reported gap between PTs' knowledge about and application of TPACK (So & Kim, 2009). The PMTs in this group possessed similar knowledge and behaviors about technology integration with the technology-infusive teachers determined by Yeh, Lin, Hsu, et al. (2015). Technology-infusive teachers tended to empower the affordances of the technologies to identify and support students' learning needs and styles and to support instruction to enhance students' self-construction of knowledge. They provided student-centered implementation suggestions to conceptualize the content with high interaction between teacher and the students (Yeh, Lin, Hsu, et al., 2015) which was the case for the PMTs' planning and implementations in this group.

The PMTs in the *Mostly Reflective Application Group* designed and implemented technology-integrated mathematics lessons to enhance students' learning, to facilitate both teacher's and students' exploration and construction of mathematical knowledge, and building connections between concepts through strategic, skillful, flexible, purposeful, and meaningful uses of technology. For instance, P11 utilized an activity on GeoGebra for identifying students' needs and prior knowledge about properties of geometrical shapes and managed the instruction accordingly which was about the properties and area of a parallelogram. PMTs revised the objectives in the curriculum and demonstrated the relationships between the objectives through construction and multiple representations with technologies. Their lesson designs included dynamic construction and manipulation which would not be conducted with paper and pencil. For instance, GeoGebra was incorporated to demonstrate dynamically the change of the place of height of a triangle and the relationship between height and base in three types of triangles in P1's implementation. In addition to their lesson plans and implementations, in the interviews PMTs emphasized the importance of student-centered strategies to facilitate students' exploration of mathematical phenomena and to construct both their own learning and students' learning through technology integration. Both of the PMTs in this group preferred to utilize GeoGebra to support students to construct their own knowledge, a highest level characteristic that was examined in PMTs' use of dynamic geometry software (i.e., Akkaya, 2016). In this group, PMTs' knowledge about and skills of technology integration to mathematics education met the intended characteristics of teachers in the highest level of TPACK-P.

The selection of the technologies adaptable with the subject and the selection of appropriate instructional methods are important for planning and designing curriculum goals (Niess et al., 2009). The technologies used in the three groups served as instructional necessities rather than substitutes for other tools. Mathematics content was found to be the determinant for technology preferences of PMTs. They thoroughly examined the affordances of the technologies to effectively represent the content. In addition to the technology selection appropriate with the content, another important decision was the pedagogical strategies employed to empower the technology-infused instruction. In the related studies about PTs' mathematics content-specific TPACK development, it was examined that PTs recognized the need for a pedagogical shift when technology was integrated to course and they tended to design and implement student-centered courses or activities (e.g., Agyei & Voogt, 2012; Cavin, 2008; Haciomeroglu et al., 2010). Although all of the PMTs' views reflected student-centered uses of technology, in practice this was not the case for all. In contrary to their knowledge about a range of instructional strategies that would fit to their lesson plans, the lesson plans were not qualified in terms of instructional activities such as drill and practice as was the case of PTs mentioned in similar studies (e.g., Mouza & Karchmer-Klein, 2013). The lack of experience of classroom practices (Koh & Divaharan, 2011) could have been the reasons for the poor pedagogical strategies implemented in the micro-teachings.

6.2.2 PMTs' TPACK-P Levels within Pedagogical Domains

PMTs' TPACK-P development was discussed on a horizontal basis above. Their progress was also examined from another perspective to reveal their TPACK-P development vertically within the three pedagogical domains of TPACK-P which are Assessment domain, Planning and Design domain, and Enactment domain. Besides, PMTs' knowledge about and application of TPACK-P in Planning and Design domain and Enactment domain were compared.

Technological tools could be transformed for pedagogical purposes (Koehler & Mishra, 2009) such as assessment and evaluation. PMTs' technology utilizations for pre-assessment and post-assessment purposes reflected different levels of TPACK-P changing from level 2 to level 4. There was one example of technology-assisted assessment in level 2. This was a post assessment application to enhance motivation, participation, and receive the performance report provided by an online assessment platform. The design of the assessment was not pedagogically supported. There was one type of question although the program served for many alternatives; the facilities of the program were not considered and used; and the PMT did not provide any feedback to the students. The technology-integrated assessments in level 3 indicated instances of assessments applied at the beginning and the end of the course. Technology-assisted prior assessments aimed to identify prior knowledge and learning needs through classroom discussions by increasing the interaction between teacher and the students which were their peers in the micro-teaching. Although all of the PMTs in level 2 were aware of the importance of identifying prior knowledge connected with the new subject and determining learning needs and misconceptions, only some of them designed and implemented technology-integrated prior assessments. Technologies were indirectly used in these prior assessments. Online assessment platforms were selected as the end-of-course assessments considering their physical properties, being user-friendly both for students and teachers, and offering different question types. The purposes of these applications were to assess and evaluate mathematical knowledge and to identify and support diverse student-learning by using different problem types, addressing different representations of the mathematics subjects, providing feedback by discussing the solution after every question, and assessing mathematical knowledge by using the performance report. The technology-infused assessments in level 4 were skillful and strategic uses of technologies. The aims added to that of level 3 were identifying misconceptions and learning needs about the mathematics concepts through online assessment programs and dynamic software, then managing the instruction accordingly. Other aims for end-of-course assessments in level 4 were evaluating students' performances, informing students about their individual performance, discussing with the students about the possible solution ways of the questions, informing teachers about the effectiveness of the instruction, and using the performance report provided by the online assessment programs to inform parents.

Assessment domain in TPACK-P framework indicates gaining information about students' learning through technology before and after the course (Yeh, Lin, Hsu et al., 2015). However, assessment and feedback is a problematic issue in terms of technology integration (Tondeur, van Braak, et al., 2012). All of the PMTs utilized online assessment programs in the present study. However, there were no technologies used for end-of-course assessment other than the online assessment programs. This could be explained by the content of the TUME course that only the online assessment programs were examined in the technology week related with assessment. Another reason for the lack of technology-infused assessment and evaluation could be the nature of traditional assessment techniques (Yeh, Lin, Hsu, et al., 2015). Pre-service and in-service teachers might depend on traditional assessment and tend to integrate technology with assessment especially at the end of the lesson. Indeed, previous studies showed that assessment is the domain which teachers have problems the most in their TPACK-P (Ay et al., 2016).

On the other hand, the prior assessments which were performed with the support of technology were exemplary applications. In prior assessments, PMTs utilized several technologies which demonstrated the consideration of the affordances of the technologies and repurposing the technologies skillfully for assessment and evaluation with supportive pedagogical strategies by addressing guiding questions to initiate a discussion. Although most of the PMTs emphasized the importance of prior assessment in the interviews, only some of them planned prior assessments with the support of technology. There were technology utilizations to identify prior knowledge and needs through displaying poster, video, and photos on Powerpoint including pictures from Pinterest. There was one example of technology-assisted assessment at the beginning of the course for the purpose of planning the instruction. The only example of assessment during the course was a construction process on GeoGebra. P11 managed the activity she created on GeoGebra by leading questions to identify students' prior knowledge and needs.

PMTs' TPACK-P proficiency levels in Planning and Design domain and Enactment domain performances were discussed together because they are interrelated domains. Studies have addressed that teachers' lesson plans and/or activity designs indicated higher TPACK than their implementations (e.g., Ay et al., 2016; Meagher et al., 2011). In fact, there were PMTs who did not implement the technology-supported activity in the micro-teaching the way they designed in the lesson plans, which also emerged in similar studies (e.g., Mouza & Karchmer-Klein, 2013; Niess, Sadri, & Lee, 2007). Moreover, about overall proficiency in TPACK-P, Ay et al. (2016) indicated that teachers had highest average in curriculum design domain, lowest point average in assessment domain, and teachers showed low proficiency skills in practical teaching domain. In the present study, some PMTs had one level difference between Planning and Design domain and Enactment domain. Although technology integration in their lesson plans were aligned with level 3 in Planning and Design domain, their levels in Enactment domain were corresponding to level 2. However, this difference was only observed in two cases. The rest of the PMTs' levels in Planning and Design domain and Enactment domain were the same. This result indicated that through the TUME course, PMTs developed their TPACK-P both in knowledge about and application of TPACK. The ability of effectively integrating technology in practice as it was planned could be explained by the effectiveness of the TUME course. Throughout the technology weeks in the TUME course, PMTs had an active designer role in planning technology-integrated activities for middle school mathematics subjects, and engaged discussions in the classroom and in an online platform about the practical application of the activities. The TUME course was developed through the practice-based and content-oriented characteristics of the TPACK-P framework which supported the view that TPACK develops for and from content-specific teaching practices (Jen et al., 2016; Yeh, Hsu, Wu, et al., 2014). Moreover, the transformative, collaborative, activity-supported, and practice-based learning principles of the TUME course were believed to influence PMTs' consistent development of both planning and practical skills as parts of their TPACK-P.

It has been the case that PTs cannot fully transfer their knowledge about technology utilization while planning (Meagher et al., 2011; So & Kim, 2009) and teaching (Jen et al., 2016) technology-integrated courses and cannot fully enact their technology-supported lesson plans during their teaching (Mouza & Karchmer-Klein, 2013). The present study also had similar findings that PMTs' knowledge and views about the role of technology in enhancing mathematics teaching and learning, which was observed in the reflections on peers' micro-teachings and in the interviews, reflected higher TPACK-P than their actual practices in the micro-teachings. In addition, PMTs' lesson plans indicated higher level of TPACK than their practices.

The TUME course had the potential and aim to encourage PMTs to use new technologies in transforming teaching. The course directed PMTs to rethink about the role of technology. Viewing technology as a tool to achieve instructional goals (Agyei & Voogt, 2012) and repurposing technology for pedagogical purposes

(Koehler et al., 2011) are the expected skills of teachers with qualified TPACK. Although PMTs were talking about how to use technology in mathematics content in the beginning of the TUME course, they were referring to the pedagogical issues such as considering student needs and learning to address by repurposing technology at the end of the course. At the beginning of the TUME course, PMTs integrated technology as an add-on tool for reinforcement without relating to the content and to pedagogical issues in their first lesson plans and they did not consider technology as a teacher competency in their responses to The Views about Teaching Profession Questionnaire. In contrary, their final lesson plans and implementations were exemplary mathematics courses where technology was incorporated for identifying students' prior knowledge and learning needs and for constructing knowledge by repurposing technological tools. PMTs' views towards the role of technology were shifted from viewing technology as a motivating tool to considering it as an instructive tool for enhancing learning, which was also reported for the case of training pre-service secondary mathematics teachers for TPACK within the methods course and field practice (Ozgun-Koca et al., 2010).

Such shift, however, was reached within a combination of experiences that were reflected on the TUME course. PMTs observed middle school mathematics courses in the context of School Experience course in their previous semesters. As the follow up course of the School Experience course, PMTs enrolled to the Teaching Experience course at the same semester with the TUME course. In the context of the Teaching Practice course, they were practicing at the collaborating middle school and they instructed lesson plans in that school. In addition, they observed middle school mathematics courses from 5th to 8th grades and gained experience about authentic classroom contexts, student characteristics, classroom management, and other aspects of teaching and learning process in these observations, and teaching practice experiences during the two semesters. PMTs mentioned about these experiences in the classroom discussions in the TUME course and in the interviews when talking about their decisions for the technology integration and pedagogical strategies in their designs. Their statements showed that observing and practicing at authentic classroom environments in the middle school affected their decisions in designing technology-infused activities through the technology weeks at the TUME course, the end-of-course lesson plans, and the micro-teaching of these lesson plans.

PMTs in the present study seemed to have the benefit of having almost completed all the courses and practice teaching at the teacher education program. They were qualified in basic computer skills through Computer I and II courses and Instructional Technologies and Material Design courses; they were familiar with the middle school mathematics content and curriculum which they comprehensively examined in the methods courses; they were trained and experienced in planning and designing mathematics courses in methods courses, knowledge of pedagogical strategies from pedagogy courses, and they had the opportunity to observe authentic mathematics courses and practiced several times in the school experience and teaching practice courses. They explicitly referred to their field experiences and one-to-one private courses throughout the course discussions and interviews. On the other hand, when PTs do not consider field experience as a support while designing technology-integrated activities and lesson plans, they do not always have the desired TPACK development (Meagher et al., 2011). Additionally, when the training that aims to develop pre-service mathematics teachers' TPACK is placed in existing courses focusing on other domains (such as content and pedagogy), the desired TPACK development does not take place (Meagher et al., 2011). Therefore, the key element in the shift in views about technology integration seemed to be PMTs' views about the benefits of teaching practice and the nature of the TUME course.

Knowledge about and application of incorporating technology to accommodate students' learning needs and supporting learning by remedying their misunderstandings correspond to skills in higher levels of TPACK-P (Jen et al., 2016). PMTs mentioned about their experiences mostly while discussing on middle students' prior-knowledge, misconceptions, learning needs, and learning styles. In addition to what they had experienced from the observations of the middle school mathematics courses, most of the PMTs implemented the same mathematics subject both in the middle school and the TUME course. Therefore, they expressed that their selection and integration of technology were depended on the learning difficulties of the middle school students which they experienced when they taught the same subject in the collaborating middle school. Similarly, in the interviews some of the PMTs also provided instances from their private courses that the purposes of their technology selections were aimed at addressing the misconceptions and learning difficulties of students. Some PMTs exemplified about situations from their experiences that they could not overcome learning difficulties about content even they had the necessary materials. They suggested several technologies to effectively support students' understanding and emphasized the strong need for technology utilization at those times.

In addition to observing and experiencing middle school students' misconceptions about mathematics subjects, PMTs detected several needs regarding other pedagogical issues such as instructional management and motivation for participation in the collaborating school and suggested technology-integrated solutions for these issues. Some of the PMTs asserted that they utilized technologies such as Smartboards in the collaborating schools and online assessment platforms in their private courses when they experienced these technologies in the TUME course. The authentic experiences in middle school classrooms encouraged PMTs to use technology in different ways for effective teaching.

PMTs' decisions of technology integration were driven from their puposes of pedagogy. For instance, if they saw the need for assessing prior knowledge and misconceptions about the subject they looked for diverse ways of effective assessment and evaluation with technology. Another instance was that the technology was considered for multiple representations to surve the purpose of differentiating instruction for students' knowledge construction in a student-centered environment. Moreover, some of the PMTs utilized the affordances of technologies to manage the student-centered instructional strategies and to track each student's progress. TPACK-P framework was proposed as a two-dimensional framework based on TPACK-P levels and three pedagogical domains. Therefore, the framework was applicable for the case of eleven PMTs in the present study for its emphasis on pedagogy.

6.3 The Influence of the TUME Course on PMTs' TPACK-P Development

The related literature embodies studies about facilitating and investigating PTs' technology integration skills through courses in teacher education (e. g., Baran & Uygun, 2016; Graham et al., 2012; Meagher et al., 2011; Meng & Sam, 2013). Similarly, the TUME course was designed for enhancing and promoting PMTs' knowledge about and application of technology in designing and implementing technology-infused mathematics courses. The content of the course was comprised of three parts which were (1) the theoretical background of TPACK and technology use in mathematics education, (2) investigation of a variety of technologies, designing technology-integrated mathematics activities, and reflecting on the designs, and (3) planning, designing, and implementing technology-infused mathematics lessons. Moreover, the TUME course content was designed and implemented with the view of TPACK as a unique body of knowledge which embraces more than the components of TPACK which was also addressed as a powerful approach by several researchers (e.g., Yeh, Hsu, Wu, et al., 2014). The results of the present study implied that the TUME course succeeded in developing all PMTs' TPACK-P because it provided introduction of several technologies, engagement in technology-related activities, practical applications of technologies in mathematics content and these were supported with collaborative work, guidance, and feedback from peers and the researcher. All PMTs' TPACK-P levels increased at the end of the TUME course. PMTs' technology integration skills developed both in planning and practice. Moreover, knowledge about and confidence towards supporting teaching and learning of mathematics with technology were developed. The possible reasons of this development were detected in the TUME course content. The progress of PMTs' TPACK-P was discussed herein after in relation with the principles and content of the TUME course.

Improving PTs' technology utilization skills effectively requires meaningful and supportive integration of effective approaches (Chien et al., 2012; Mouza et al., 2014). After reviewing the 19 qualitative studies related with TPACK, Tondeur, van Braak, et al. (2012) stated that linking theory with practice, the teacher educator being the role model, learning technology integration by designing, and working collaboratively with peers were among the key factors that affect PTs' technology integration. Based on the related literature, a *transformative approach* including *collaborative learning*, *activity-supported learning*, and *practice-based learning* were determined as the effective approaches to be utilized to serve the aim of the TUME course and the present study. These were designated as the four principles that the TUME course was grounded on to develop PMTs' technology integration knowledge and practices, namely their TPACK-P. In addition to the emphasis in the literature, these principles were also covered in the TPACK-P framework (i.e., Yeh, Hsu, Wu, et al., 2014, 2015; Jen et al., 2016).

The design and implementation of the TUME course, data collection tools, data analysis, and interpretation of the findings were based on TPACK-P framework which reflected transformative view towards TPACK. TPACK is a unified and distinct body of knowledge that cannot be restricted to its sub knowledge domains (Angeli & Valanides, 2009, 2015; Thompson & Mishra, 2007; Yeh et al., 2014) and the complex combination of knowledge constructs that emerge within teachers' knowledge and practices (Jen et al., 2016). Therefore, interpreting the findings of the study with an integrative view of TPACK, which fails to explain technology integration in components of teaching and learning practices (Angeli & Valanides, 2009), would be limited. All of the PMTs were aware of various technologies and experienced their use for educational purposes in some of their courses. Hence, they were well-equipped with technological knowledge before the TUME course as evidenced in the Technology Usage Questionnaire which was gathered at the beginning of the TUME course. They had completed content-related courses and examined the middle school mathematics content thoroughly in the two of the Methods courses. They had completed most of the pedagogical courses before enrolling to the TUME course. From an integrative view, being equipped with technological knowledge, pedagogical knowledge, and content knowledge would have reflected its effect on the prior lesson plans of the participants. However, all of the PMTs were detected at level 1 proficiency level of TPACK-P. Almost half of them could not provide an original technology-integrated lesson plan. The rest of the PMTs who submitted technology-integrated lesson plans used technology for demonstration of pictures and motivating students. There were no aims for enhancing instruction, supporting learning, or identifying students' needs through technology utilization.

The TUME course was designed and implemented from a *transformative view* towards TPACK with the aim of "preparing teachers to customize subject-specific curricula with a consideration for both learners and contexts, through a recursive process of instructional planning, enacting and reflecting" (Yeh, Hsu, Wu, et al., 2014, p. 710). At the end of the TUME course, all of the PMTs performed higher proficiency levels and their efforts of technology integration showed elaboration of three knowledge constructs that form TPACK. Form an integrative view, PMTs would also be expected to show similar competency in utilizing technology in planning, assessment, and implementation of the lesson plans at the end of the TUME course. However, most of the PMTs' technology integration levels differed among the domains. For instance, PMTs performing at higher levels in Planning and Design domain could not show similar performances in Assessment domain. Their performances also differed in technology utilization for different assessment purposes. Technology-incorporated end-of-course assessments were exemplary. However, effective technology integration for prior assessment purposes was not examined in all plans and implementations.

The other principles of the TUME course were *collaborative learning, activity-supported learning,* and *practice-based learning* which promoted PMTs' TPACK-P development. Collaborative work in designing technology-enhanced teaching materials enriches development of TPACK (Agyei & Voogt, 2012; Koehler & Mishra, 2005; Koehler, Mishra, & Yahya, 2007, Polly et al., 2010, Tondeur, van Braak, et al., 2012). Moreover, collaborative work empowers designing high level quality materials suitable for practical use (Yeh et al., 2015). PMTs developed TPACK through developing their technology integration competencies by engaging collaborative design activities, completing all of the required tasks of the TUME course within the class as a group through exchanging ideas, experiences, and skills, and sharing their activities online on Facebook course page. Interacting with each other while designing technology-integrated products in every activity and discussion, reflecting on each other's technology-integrated activity designs at the technology weeks, and peer- and self-reflections upon the micro-teachings triggered PMTs to think critically. These altogether assisted to develop and evaluate PMTs' TPACK-P. Engaging in designs activities about technology integration, collaboration with peers, and providing feedback have been some of the effective strategies in teacher education programs to develop PTs' competencies about effective technology integration in classroom practice (Tondeur, van Braak, et al., 2012). Similar results were revealed in the practice-based study conducted by Cavin (2008) that PTs developed TPACK through micro-teaching experiences through an undergraduate course. PTs engaged in a cycled-practice in which they worked in groups and thought, reflected, and modified technology-integrated mathematics courses repetitively. PTs indicated that collaborative work with peers facilitated their technology-integrated lesson designs (Cavin, 2008).

In the process of developing TPACK, teachers are expected to seek for the ways in which technologies best match with several pedagogical strategies and content to support and enhance learning (So & Kim, 2009). In this respect, the activities in the technology weeks provided a fruitful environment for PMTs to search for the best matches of technology, pedagogy, and content by exchanging ideas and criticizing each other's designs. PMTs gained an active role in technology supported activity planning in technology weeks and through lesson planning at the end of the course. Collaborative work and active engagement in designing technology-integrated materials were effective strategies for TPACK development (Lee & Lee, 2014; Mouza et al., 2014). Agyei and Voogt (2012) investigated the influence of working in collaborative design teams on four PMTs' integration of technology-enhanced lessons and on their TPACK. It was found that active engagement in design teams supported PMTs' TPACK development. According to Lee and Lee (2014) being a designer provides PTs an active role while building connections between technology, pedagogy, and content. It was found in recent research that designing activities supports critical thinking about what kind, why, and how about incorporating technology to teaching and learning (e.g., Meagher et al., 2011). Activity-supported learning shifts the focus from teacher-centered approach to student-centered learning (e.g., Agyei & Voogt, 2012) which was indicated in PMTs' final lesson plans, implementations, and interviews.

TPACK-P is a knowledge construct that educators develop from their own practices with technology and for using technology in practice (Jen et al., 2016). Emphasis on practical use of technology is needed (Niess, 2008; Voogt et al., 2016) and observations can unveil TPACK in practice (Koehler et al., 2012). Practice-based content of the TUME course aimed at developing and strengthening participants' TPACK-P through interaction with technologies, engaging technology-enhanced activities in a supportive environment, and creating and implementing technology-integrated designs as suggested by Jen et al. (2016). The high level of practical skills of the PMTs in the micro-teachings could be linked to their active role and practical experiences with technologies in the activities through the TUME course.

In most of the studies which aimed at development and assessment of PTs' TPACK in mathematics content, the technology was limited to one or at most four software (e.g., Agyei & Voogt, 2012; Chai et al., 2013; Durdu & Dag, 2017; Kurt, 2016; Meagheret al., 2011; Meng & Sam, 2013; Ozgun-Koca et al., 2010), which in turn limited PTs' selections of the mathematics subjects to some extent. The studies in the accessible literature did not report a course introducing both general and content-specific technologies to develop PTs' TPACK in mathematics. Considering these, in the present study, the technologies introduced in the context of the TUME course were adaptable to be used in accordance with diverse pedagogical strategies and mathematics subjects. This provided PMTs with the opportunity to reconsider the entire middle school mathematics curriculum by deciding the technology they selected to utilize. The PMTs were introduced with both content-specific technologies (i.e., virtual manipulatives and interactive games, graphing calculators and GeoGebra as dynamic environments, Smart

Boards) and general technologies (i.e., online visual sharing platforms, concept map preparation applications, poster and infographic programs, quiz preparation programs and online assessment programs, video editing applications). After introducing the technologies, PMTs designed and offered activities supported with pedagogical strategies within the context of middle school mathematics curriculum. PMTs were able to recognize the ease of use and benefit of technology and built interrelationship between these technologies, pedagogical strategies, and middle school mathematics subjects when they experienced various technologies through the TUME course. PMTs were free to choose technologies to adapt in their final lesson plan and implementations. It was revealed that they utilized various general and content specific technologies according to the purpose of their designs. Moreover, all of the PMTs explored mobile applications (i.e., mind map, graphing calculator ClassPad, poster, 3D, Pinterest, Video Show) intentionally, developed an expertise for them easily, and integrated them in their group works through several activities. In the interviews, PMTs provided instances from how they utilized mobile applications with middle school students in the collaborating middle school and in the private courses. When the types of technologies PMTs utilized at the final lesson plans were compared with the technologies introduced in the context of the TUME course, it was ascertained that PMTs incorporated most of the technologies they experienced in the context of the TUME course. The other technologies (i.e., online games, graphing calculator) that were not included in the lesson plans and micro-teachings were suggested for use in the peer-reflections and interviews.

The literature indicated that teachers' confidence in using technologies was low and teacher education programs can support them with several practices to raise their confidence (Kaufman, 2015). In the present study, all of the PMTs expressed at the end of the TUME course that they were confident in using technologies. They also mentioned that they would lead other teachers for integrating technologies in mathematics courses in the future, which might indicate their increased confidence in employing appropriate technologies in teaching mathematics. Such intentions for leadership was expressed explicitly in one of

ISTE standards for educators that teachers should be leaders who “model for colleagues the identification, exploration, evaluation, curation and adoption of new digital resources and tools for learning” (ISTE, 2017, p. 1). IT might be the case that the content and the implementations of the TUME course also provided PMTs the confidence for the leadership in technology integration.

Teachers are expected to be skillful in effective use of new technologies in education (OECD, 2010). However, pre-service and in-service teachers struggle about technology integration with appropriate pedagogical strategies to effectively teach content when new technologies are offered in education (Yeh, Lin, Hsu, et al., 2015). Experiencing and exploring successful technology-infused practices with several types of technologies, teachers can develop confidence towards integrating technology to education (Yeh, Lin, Hsu, et al., 2015) which was accomplished in content-specific teacher education courses (e.g., Agyei & Voogt, 2012; Ozgun-Koca et al., 2010). PMTs in the first group in the present study indicated that they were comfortable with using only the technologies they experienced in the TUME course. The PMTs in the other two groups expressed that they felt confident about using new technologies and integrating them in mathematics education, as similar studies reported (e.g., Ozgun-Koca et al., 2010). However, regardless of their improved confidence towards integrating technology in their future teaching, PTs tend to be reluctant to utilize technology in their implementations when it is not compulsory (Ozgun-Koca et al., 2010). Although it was compulsory, all of the PMTs in the present study both improved confidence and willingness towards technology-integration and demonstrated effective integration in their lesson plans and/or implementations and did not present only lack of motivation to integrate technology. The gains from the TUME course requirements, which were based on engaging actively in the technology-integrated design processes, provided extensive experience with technology to adapt in middle school mathematics content. PMTs were also encouraged to repurpose technological tools which in turn developed their confidence towards using not only the technologies they experienced in the course but also new technologies they would meet in the future.

PMTs' TPACK-P proficiency levels indicated a balanced development considering the three domains. There were no participants with more than one level difference between the TPACK-P proficiency levels in three domains. The levels of each participant in three domains were either the same (i. e., P3, P8, P10, and P11) or there was one level difference between them (i. e., P1, P2, P4, P5, P6, P7, and P9). For example, a participant performing at level 2 in one domain did not perform at level 4 in another, or a participant labeled at level 4 in one domain, did not perform at 2 or 1 in the other domains. This demonstrated that participants who recognized the affordances of the technologies and how to adapt in teaching showed close performance in integrating technology to planning, implementation, and assessment. Every participant acknowledged similar knowledge and application in three domains. Therefore, the proximity of levels was +1 or -1 difference in three domains which was considered as evidence that the TUME course achieved its purpose by effectively supporting the three domains together.

The findings revealed that increase was detected regarding all PMTs' TPACK-P proficiency levels at the end of the TUME course. However, all of the PMTs did not reach at the intended level, which was level 4, in terms of knowledge about and application of TPACK-P. This shows that a single course, the TUME course, might not be sufficient for the desired development of TPACK-P for all PMTs. Similarly, Akyuz (2016) expressed that it was unlikely for all of the PTs to develop TPACK in a limited time within one course. In the present study, the teacher education program that the PMTs were enrolled in was comprised of a variety of courses supporting PK, CK, and TK. On the other hand, there were no courses aimed at developing all of them in a combined approach and the TUME course was the only course in the program based on transformative view designed for developing PMTs' TPACK. In their critical review of the intervention studies concerning TPACK development, Chai et al., (2013) asserted that there appeared the need to redesign multiple courses to enhance PTs' technology-integrated design skills. Therefore, TUME course might be considered as a good example of such courses.

TPACK is a multifaceted knowledge type which involves the effective incorporation of technology in teaching (Angeli & Valanides, 2009; Niess, 2005). Similarly, Koehler and Mishra (2009) defined TPACK as the professional knowledge which necessitates the ability to "flexibly navigate the spaces defined by the three elements of content, pedagogy, and technology and the complex interactions among these elements in specific contexts" (p. 66) to create effective and unique solutions. Meaningful selection and integration of technologies to middle school mathematics content were evident in PMTs' final lesson plans and implementations. However, none of them provided or implemented the intended level of flexible and creative technology incorporation to identify and address students' learning needs and to enhance learning. To remedy the lack of repurposing of tools to serve pedagogical aims, PMTs could be provided with more authentic experiences with designing lesson plans and activities and implementing those activities in micro-teaching and middle school classrooms which afford technological equipment.

6.4 TPACK-P Framework

TPACK-P framework was constructed with the participation of researchers and teachers in the science field. Therefore, this framework was named to be a science content-specific framework (Angeli et al., 2016). Although it was asserted that this framework would be different with the contributions of researchers and educators from other fields (Angeli et al., 2016), the benchmarks and the indicators in the framework was adequate to analyze the data gathered in a mathematics teacher education context in the present study. This might be the reason that science and mathematics have been interrelated fields of education and technology integration serves for similar purposes in both fields.

There were limitations in the framework in terms of pedagogical aspects. To start with, the indicators in the framework do not explicitly cover management-related competencies. Effective technology practices in teaching would result in increase of teachers' abilities to manage student learning (Yeh et al., 2014). In their initial model, Yeh et al. (2014) proposed instructional management as one of the eight knowledge dimensions of TPACK-P framework. This knowledge dimension covered teahcers' ability to identify the affordances of technologies on instructional management and to use technology skillfully in this regard. Then, this knowledge dimension was placed under enactment pedagogical domain in the framework (Jen et al., 2016). However, technology use for instructional management purposes was only indicated in levels one and three. In other levels this dimension is implicitly stated and it was left to researchers' interpretations. In this case, it may be suggested that the role of technology in teaching management is clearly expressed at each level in both knowledge about and application of its use.

Another limitation of the framework was that the practice-based actions were not present in the indicators of low levels. For instance, statements indicating teachers' practical implementations such as *use various representations*,", and *utilize functions of technology to facilitate exploration* in level 4, *use appropraite technology*, *implement appropriate multimedia*, and *implement appropriate digital representations* in level 3, and *use online assessments* and *use different representations* in level 2 were examples for action-related statements (i.e., Jen et al., 2016). These levels lack statements about knowledge of TPACK-P. On the other hand, the indicators in level 1 reflected statements only about teachers' views of TPACK-P such as *think technology supported* assessments which were not different from conventional assessments and had concerns regarding implementing ICTs. The indicators did not consist statements about what was lacked in the implementations of these teachers in level 1. These indicators need to be extended considering knowledge of and application of TPACK-P in each level and domain since since TPACK-P was proposed as both knowledge-based and practice-based framework. The knowledge and applications of PMTs in the present study could serve as examplary behaviors to state new indicators or extend the existing ones in four levels.

6.5 Implications and Recommendations

In this section, implications and recommendations were provided in light of the results of the present study. The implications and recommendations referred to two main issues. The first issue was about integrating the TUME course in teacher education programs as an approach for PMTs' TPACK-P development. The other issue was about transformation of other courses in teacher education programs for promoting PMTs' proficiencies in terms of knowledge about and application of technology integration to education, thereby enhancing PMTs' TPACK-P.

6.5.1 Implications for Practice

This study contributed the field with the meticulously designed undergraduate course. The design and implementation of a TPACK development course relying on four design principles were explained in detail in the methods chapter. The course demonstrated design and implementation suggestions for teacher educators to plan and conduct similar context-specific courses. The course was based on certain main characteristics. To start with, the TUME course was designed based on four principles about pedagogical approaches for TPACK development which were transformative approach (Angeli & Valanides, 2005, 2009; Yeh, Hsu, Wu, et al., 2014), collaborative learning (Koehler & Mishra, 2005; Tondeur, van Braak, et al., 2012; Yeh, Lin, Hsu, et al., 2015), activity-supported learning (Agyei & Voogt, 2012; Harris & Hofer, 2009; Yeh, Lin, Hsu, et al., 2015), and practice-based learning (Jen et al, 2016; Yeh, Hsu, Wu, et al., 2014; Yeh, Lin, Hsu, et al., 2015). Secondly, the TUME course covered a variety of technologies that serve for several educational aims. The course was not limited to one or a few technologies. Rather, PMTs were encouraged to meet, explore, and incorporate many technologies when designing mathematics activities. The other major characteristic of the course was that it covered all middle school mathematics content rather than focusing on a single mathematics subject. The national middle school mathematics curriculum content (MoNE, 2013) covered five learning areas that were numbers and operations, algebra, geometry, measurement, and data analysis. The PMTs were free to choose any learning objective from any of these five learning areas from fifth to eighth grades when designing technology-integrated activities and lessons. One of the unique characteristics of the TUME course was the timing of the course and the experiences of the PMTs in the program. The course was offered to the PMTs who were in their last semester in the teacher education program. PMTs have completed almost all the courses in the program and were placed in collaborating school for their teaching practice. Therefore, they were able to design and implement technology-infused lesson plans by making use of their cumulative experiences in the program. Being in the last semester of the teacher education program might have motivated PMTs to pay more attention to the TUME course experiences and make sense of these experiences considering their teaching practice, even though they did not implement their lesson plans in middle school settings. Therefore, it can be considered as an exemplary model of effective incorporation of technology for PTs to experience as students (Niess, 2005) and as teachers.

Research on developing PTs' technology incorporation skills pointed on the need for revising the entire teacher education curriculum accordingly (Tondeur, Pareja-Roblin, van Braak, Fisser, & Voogt, 2013). Promoting PTs' technological awareness for designing and enacting student-centered mathematics courses (Huang & Zbiek, 2016) can be realized by infusing technology systematically and inclusively in all courses offered in teacher education programs (Mouza et al., 2017; Tondeur, Scherer, et al., 2017). Literature provides effective course designs which attempted to enhance PTs' TPACK in mathematics by redesigning methods course (Haciomeroglu et al., 2010; Lee & Hollebrands, 2008; Meng & Sam, 2013; Ozgun-Koca et al., 2010), teaching practice course (Agyei & Voogy, 2012; Balgalmis, 2013), mathematics courses (Durdu & Dag, 2017; Kurt, 2016; Meagher et al., 2011), multiple of these courses concurrently (Mudzimiri, 2012; Niess, 2005) or designing new courses (Akkaya, 2016; Akyuz, 2016; Bowers & Stephens, 2011; Cavin, 2008). Among these, infusing technology to methods courses and field practices supported development of PTs in terms of technology integration (Mishra et al., 2009; Niess, 2012; Polly et al., 2010). The TUME course content covered the content of these two courses to enhance and evaluate PMTs' TPACK-P by providing them opportunities in which they develop TPACK-P from and for their experiences with technology. The practice courses are believed to provide PTs with the opportunity to enact their technology-integrated lesson plans and develop their knowledge about and application of TPACK, thereby develop their TPACK-P.

This study does not intend to present the best course model for developing and assessing PMTs' TPACK, rather to provide an approach for the development and identification to foster teacher educators to consider the issue. The increased TPACK-P levels of PMTs showed the positive influence of the TUME course. The principles, content, and implementation details of the TUME course was believed to take researchers' attention to rethink about how TPACK can be developed through an integrated course. The TUME course with its principles and content could be implemented in other teacher education programs. Evaluation of the influence of the TUME course on other PMTs' TPACK-P would contribute to the content of the TUME course. Moreover, the course can be instructed with the same principles in teacher training programs for PTs' TPACK-P development with modifications.

This study revealed promising results that was achieved within a single course which aimed at developing PMTs' technology integration competencies. However, all of the PMTs did not reach at the intended level which was level 4 in terms of knowledge about and application of TPACK-P. PTs' technology integration skills need to be developed through multiple courses to enhance the development of TPACK (Akyuz, 2016; Chai et al., 2013; So & Kim, 2009). Then, it would be expected for all PTs to reach the intended proficiency level of TPACK-P. Therefore, the content of the teacher education programs needs to be revised in a more systematic way (So & Kim, 2009). For instance, Ay et al. (2016) indicated that PTs' technological knowledge and integration skills need to be enhanced in teacher training especially within the context of Instructional Technologies and Material Design course, School Practice course, and Teaching Experience course or the courses with different names but similar contents with these. Niess (2011) suggested that investigation efforts regarding TPACK can lead teacher educators to reconsider and revise the teacher preparation programs. She also suggested alternative ways to develop and measure TPACK. The results of this study presented promising development of TPACK-P in the context of an undergraduate teacher education program. In the present study, the technologies that were utilized and the ways of integrating them should be considered in the context of EME programs in teacher training courses. Policy makers should initiate this reforn process in all teacher education programs. The more PTs experience technology-integrated activities, the more they will understand the relationship between technology and pedagogy (Koh & Divaharan, 2011) within content.

The present study was grounded on TPACK-P framework. Hence, one of the principles of the TUME course was practice-based learning. The results of the study showed that the TUME course promoted PMTs' technology integration knowledge and applications derived from and for their practices with technology, thereby their TPACK-P. TPACK is embedded in experience and develops through practice (Yeh, Lin, Hsu, et al., 2015). PTs need opportunities to demonstrate their knowledge in practice (Niess, 2008). Therefore, this study suggests that the courses in teacher education programs should guide PTs both to design and practice the technology-integrated instructions. Practice opportunities should be provided more in teacher education within the context of multiple courses for increasing the proficiency in Enactment domain. Related studies (e.g., Kurt et al., 2014) referred to the importance of transformation of teacher education course contents to include both design and practice of technology integrated instructions. The need for offering technology-rich methods courses and field practice together for PTs to develop their TPACK and instructional practices in designing and implementing technology-enhanced courses has been a concern in the field (Meagher et al., 2011; Polly et al., 2010). Therefore, consistent integration of technology in content, methods, and field experience courses to develop PTs' technology implementation skills (Huang & Zbiek, 2016) should be considered in teacher education programs.

Technological tools could be transformed for pedagogical purposes (Koehler & Mishra, 2009) such as assessment and evaluation. Technology-integrated assessments allow evaluation of various skills and knowledge that traditional assessment techniques cannot achieve. Although there was no indication about use of technology for assessment purposes at the beginning of the TUME course, PMTs utilized technology for several assessment purposes such as assessing students' prior knowledge, misconceptions, learning needs, learning styles, mathematics knowledge, and the effectiveness of the instruction by using online assessment programs and/or repurposing other technological tools such as Powerpoint presentation, poster, Pinterest, and GeoGebra. Their technology utilizations for pre-assessment and post-assessment purposes corresponded to the indicators in different levels of TPACK-P changing from level 2 to level 4. However, there were no technologies used for end-of-course assessment other than the online assessment programs. This could be explained by the content of the TUME course that only the online assessment programs were examined in the technology week related with assessment. The Measurement and Evaluation course in teacher education programs can introduce technology-supported assessments to PMTs and demonstrate that every technology can be transformed for assessment purposes. Another reason for the lack of technology-infused assessment and evaluation could be the dominance of traditional assessment techniques (Yeh, Lin, Hsu, et al., 2015). In teacher education courses, PMTs' performances could be assessed and evaluated through technology such as e-portfolios (Tondeur, van Braak, et al., 2012).

The technological constraints in the middle schools prevented PMTs to practice technology use in authentic classroom environments since Internet, mobile phones, computers, tablets, or laptops were not allowed in the collaborating middle schools. Some classrooms only had projection software and a few included Smartboards which were provided in the FATIH project. However, PMTs emphasized that these were not actively used by the mathematics teachers in the middle schools. The middle schools need technological equipments in this regard. The major equipments could be listed as the Internet, computers, and Smartboards. In addition, the general and mathematics content specific technologies which were utilized in the context of the TUME course can be downloaded to the computers. In addition, PMTs utilized or recommended the use of all of the technologies which they experienced in the TUME course in their designs. Therefore, the general and mathematical specific technologies used within the scope of the TUME course should be accessible in schools. Moreover, both teachers' and students' access to these programs need to be provided. Because, PMTs in the higher levels of TPACK-P desgined and implemented student-centered mathematics courses in the present study in which they gave the responsibility to the students to construct their own knowledge and meet their needs.

Middle school mathematics teachers' professional development also needs to be enhanced. Teachers can be supported within their training programs by similar content-based, activity-supported, practice-based, and collaborative design and enactment trainings as in the TUME course. These trainings would serve them with designs and practice experiences which they can use in their mathematics classrooms. In Turkey, Educational Informatics Network (EBA) provides a wide range of materials for teachers in all fields. Moreover, there is a variety of technology utilization suggestions and implementations in the videos on the website (i.e., EBA, 2018). However, this network is only allowed to be accessed by the public school teachers. It could also be available to private school teachers, PTs, and teacher educators.

6.5.2 Recommendations for Research

The present study contributed to the practice-based studies by specializing the framework to mathematics field. The study was grounded on TPACK-P framework proposed by Yeh, Hsu, Wu, et al. (2014) and Yeh, Lin, Hsu, et al. (2015). Although researchers and educators in science education contributed to the generation of the TPACK-P framework by their remarks (Jen et al., 2016; Yeh, Lin, Hsu, et al., 2015), the framework presented TPACK proficiency levels that were applicable to PTs and in-service teachers of all fields. Knowledge and behaviors corresponding to each proficiency level seemed content-specific at first sight that there were *science* words among the indicators and behaviors identified for the proficiency levels. The word *science* was converted to *mathematics,* which did not result in any ambiguity regarding the intended meaning of the indicators. This was the only aspect of the framework pointing at science education. There was no need for major changes while modifying the rubric for mathematics content. Therefore, the framework could be considered to fit for further studies investigating PTs' and in-service teachers' TPACK in mathematics.

On the other hand, Jen et al. (2016) provided exemplary behaviors of teachers corresponding to the TPACK-P proficiency levels in three domains. Some of these behaviors were incompatible with mathematics. For instance, as an exemplary teacher behavior, the use of simulations pertains to science field applications that cannot be exemplified in a mathematics course. These science content-related behaviors were still giving idea for the TPACK-P components they included. These example behaviors were supportive for understanding the meaning of the indicator and the level they belonged to. Therefore, they were used as example behaviors for the analysis of PMTs' knowledge and actions in the present study. These science-related behaviors were inserted to the table of the framework and used as a rubric in the present study. This rubric was used to analyze all the data obtained from the PMTs, and then to detect PMTs' TPACK-P levels in the beginning and end of the TUME course. Although the TPACK-P proficiency levels, indicators, and related behaviors were developed through extensive research conducted by teachers, PTs, and researchers (Yeh, Hsu, Wu, et al., 2014; Jen et al., 2016), a different sample of PTs in this study provided additional characteristics and behaviors. These additional knowledge and behaviors were either general or mathematics content-specific which were presented in detail in the findings chapter. These provided exemplary knowledge and behaviors corresponding to all of the four TPACK-P proficiency levels in three domains, which would be useful for researchers who intend to conduct general or mathematics content-specific TPACK studies. This was a significant contribution of the present study that can lead further studies to analyze and validate their results in comparison with these behaviors in similar settings. This was also a contribution to the TPACK-P framework in terms of providing additional behaviors belonging to its levels and domains.

The low number of participants in the Mostly Reflective Application group, representing Level 4, indicated that more practice was needed for the rest of the participants to achieve technology integration skills at this level. Considering that the TUME course content mostly included student-centered activities and discussions about technology, technology-enhanced course designs, and micro-teaching practices, it would be useful to provide participants with practices in authentic settings. As mentioned in the methods chapter, participants had been observing the mathematics courses in the context of the field observation course in the previous semester. Then, in the same semester with the TUME course, participants experienced teaching in the same middle school in the context of the teaching experience course. Participants mentioned about their observations and teaching experiences in the middle school through their designs and discussions in the TUME course and in the interviews. They provided instances that they had experienced in the collaborating middle school. The middle school experience affected PMTs' designs and implementations of technology-integrated activities and courses and their views towards technology utilization in the TUME course. All of the participants expressed that they considered middle school students' needs and misconceptions they observed in their observations in the collaborating school while preparing technology-integrated plans and implementations in the TUME course. PMTs' statements about their experiences in the middle school revealed the pedagogical rationale behind their technology selections. Therefore, the influence of authentic classroom observation and practicum on PMTs' technology-infused design decisions needs be investigated thoroughly in further studies.

PMTs' implementations of technology-integrated courses were observed through micro-teaching practices in the faculty classroom instead of observing them at the mathematics classrooms in the collaborating middle school. The reason was the technological constraints in the middle schools that Internet, mobile phones, computers, tablets, or laptops were not allowed in the school. Some classrooms only had projection software and a few included Smartboards. The lack of technological equipments in the practice schools did not provide a sufficient context for the implementation of the technology-integrated lesson plans that PMTs designed. Therefore, micro-teaching technique was used to allow teacher candidates with more technological tool choices, which would have affected their designs. Studies focusing on the development of PTs' technology integration skills and TPACK point out to the importance of authentic experience provided to PTs in teacher education programs (Tondeur, van Braak, et al., 2012). In future studies, schools that are equipped with the Internet connection and technologies such as

Smart Boards and computer laboratories can be selected to investigate PTs' TPACK-P development in authentic settings in field practice courses.

In the present study, PMTs selected objectives from the middle school mathematics curriculum, which they decided that the technologies would support students to reach that objective, and then designed activities and lesson plans with suitable instructional strategies. These activities can be expanded in time and become a longitudinal study. It can be suggested to support and monitor PTs in these courses through time and enhance their technology integration skills in mathematics education according to their needs. The PTs can be monitored in terms of their TPACK development through the entire teacher education program. This would help to improve the content of teacher education curricula which would improve PTs' TPACK.

REFERENCES

AACTE (Ed.). (2008). *Handbook of technological pedagogical content knowledge (TPCK) for educators.* New York: Routledge

Agyei, D. D., & Voogt, J. M. (2011a). Exploring the potential of the will, skill, tool model in Ghana: Predicting prospective and practicing teachers' use of technology. *Computers & Education*, *56*(1), 91-100.

Agyei, D. D., & Voogt, J. (2012). Developing technological pedagogical content knowledge in pre-service mathematics teachers through collaborative design. *Australasian Journal of Educational Technology*, *28*(4), 547-564.

Akbaba-Altun, S. (2006). Complexity of integrating computer technologies into education in Turkey. *Journal of Educational Technology & Society*, *9*(1), 176-187.

Akkaya, R. (2016). Research on the Development of Middle School Mathematics Pre-Service Teachers' Perceptions Regarding the Use of Technology in Teaching Mathematics. *Eurasia Journal of Mathematics, Science & Technology Education*, *12*(4), 861-879.

Akyuz, D. (2016). TPACK analysis of preservice teachers under different instruction methods and class levels. *Turkish Journal of Computer and Mathematics Education*, *7*(1), 89-111.

Association of Mathematics Teacher Educators. (2006). Preparing teachers to use technology to enhance the learning of mathematics: A position of the Association of Mathematics Teacher Educators. Retrieved from January 5, 2018 from http://www.amte.net/Approved%20AMTE%20Technology%20Position%20Paper.pdf

Angeli, C., & Valanides, N. (2005). Preservice elementary teachers as information and communication technology designers: An instructional systems design model based on an expanded view of pedagogical content knowledge. *Journal of Computer Assisted Learning*, *21*(4), 292-302.

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & Education, 52*(1), 154–168.

Angeli, C., & Valanides, N. (Eds.). (2015). *Technological pedagogical content knowledge: Exploring, developing, and assessing TPCK*. NY: Springer.

Angeli, C., Valanides, N., & Christodoulou, A. (2016). Theoretical considerations of technological pedagogical content knowledge. In M. C. Herring, M. J. Koehler, & P. Mishra (Eds.), *Handbook of technological pedagogical content knowledge (TPACK) for educators*, (2^{nd} ed., pp. 11-33). New York, NY: Routledge.

Aslan, A., & Zhu, C. (2016). Influencing factors and integration of ICT into teaching practices of pre-service and starting teachers. *International Journal of Research in Education and Science (IJRES)*, *2*(2), 359-370.

Aslan, A., & Zhu, C. (2017). Investigating variables predicting Turkish pre- service teachers' integration of ICT into teaching practices. *British Journal of Educational Technology*, *48*(2), 552-570.

Association of Mathematics Teacher Educators (2009). *Mathematics TPACK (Technological Pedagogical Content Knowledge) Framework.* Retrieved February 8, 2018 from http://www.amte.net/sites/all/themes/amte/resources/AMTETechnologyPositionStatement.pdf

Ay, Y., Karadag, E., & Acat, M. B. (2015). The Technological Pedagogical Content Knowledge-practical (TPACK-Practical) model: Examination of its validity in the Turkish culture via structural equation modeling. *Computers & Education*, *88*, 97-108.

Ay, Y., Karadag, E., & Acat, M. B. (2016). ICT Integration of Turkish Teachers: An Analysis within TPACK-Practical Model. *International Journal of Progressive Education*, *12*(2), 149-165.

Balgalmis, E. (2013). *An investigation of pre-service elementary mathematics teachers' techno-pedagogical content knowledge within the context of their teaching practices* (Unpublished doctoral thesis). Middle East Technical University, Ankara, Turkey.

Bakir, N. (2016). Technology and teacher education: A brief glimpse of the research and practice that have shaped the field. *TechTrends*, *60*(1), 21-29.

Baran, E., & Canbazoglu Bilici, S. (2015). Teknolojik Pedagojik Alan Bilgisi (TPAB) Üzerine Alanyazın İncelemesi: Türkiye Örneği [A review of the research on technological pedagogical content knowledge: The case of Turkey]. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi* [*U. Journal of Education]*, *30*(1), 15-32.

Baran, E., & Uygun, E. (2016). Putting technological, pedagogical, and content knowledge (TPACK) in action: An integrated TPACK-design-based learning (DBL) approach. *Australasian Journal of Educational Technology*, *32*(2), 47-63.

Bowers, J. S., & Stephens, B. (2011). Using technology to explore mathematical relationships: A framework for orienting mathematics courses for prospective teachers. *Journal of Mathematics Teacher Education*, *14*(4), 285-304.

Cakiroglu, E., & Haser, C. (2002). Mathematics teachers' perceptions of computers use in mathematics instruction: A case study from Turkey. In D. Mewborn, P. Sztajn, D. White, H. Wiegel, R. Bryant, & K. Nooney (Eds.), *Proceedings of the Twenty Fourth Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*, (Vol. II, pp. 669–672). Columbus, OH: Eric Clearinghouse for Science, Mathematics, and Environmental Education.

Canbazoglu Bilici, S., Guzey, S. S., & Yamak, H. (2016). Assessing pre-service science teachers' technological pedagogical content knowledge (TPACK) through observations and lesson plans. *Research in Science & Technological Education*, *34*(2), 237-251.

Cavin, R. (2008). Developing Technological Pedagogical Content Knowledge in Preservice Teachers through Microteaching Lesson Study. In K. McFerrin, R. Weber, R. Carlsen & D. Willis (Eds.), *Proceedings of SITE 2008--Society for Information Technology & Teacher Education International Conference* (pp. 5214-5220). Las Vegas, Nevada, USA: Association for the Advancement of Computing in Education (AACE). Retrieved May 19, 2018 from https://www.learntechlib.org/primary/p/28106/

Chai, C. S., Koh, J. H. L., Tsai, C.C. (2013). A review of technological pedagogical content knowledge. *Educational Technology & Society*, *16*(2), 31-51.

Chai, C. S., Koh, J. H. L., Tsai, C. C., & Tan, L. L. W. (2011). Modeling primary school pre-service teachers' Technological Pedagogical Content Knowledge (TPACK) for meaningful learning with information and communication technology (ICT). *Computers & Education*, *57*(1), 1184-1193.

Chien, Y. T., Chang, C. Y., Yeh, T. K., & Chang, K. E. (2012). Engaging pre-service science teachers to act as active designers of technology integration: A MAGDAIRE framework. *Teaching and Teacher Education*, *28*(4), 578-588.

Cox, S., & Graham, C. R. (2009). Using an elaborated model of the TPACK framework to analyze and depict teacher knowledge. *TechTrends*, *53*(5), 60-69.

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Sage.

Durdu, L., & Dag, F. (2017). Pre-service teachers' TPACK development and conceptions through a TPACK-based course. *Australian Journal of Teacher Education (Online)*, *42*(11), 150-171.

Graham, C. R., Borup, J., & Smith, N. B. (2012). Using TPACK as a framework to understand teacher candidates' technology integration decisions. *Journal of Computer Assisted Learning, 28*, 530–546.

Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education*. New York: Teachers' College Press.

Grossman, P. L. (1991). Overcoming the apprenticeship of observation in teacher education coursework. *Teaching and Teacher Education*, *7*(4), 345-357.

Haciomeroglu, E. S., Bu, L., & Haciomeroglu, G. (2010, July). Integrating technology into mathematics education teacher courses. In *First North American GeoGebra Conference,* 27.

Herring, M. C., Koehler, M. J., & Mishra, P. (Eds.). (2016). *Handbook of technological pedagogical content knowledge (TPACK) for educators*. NY: Routledge.

Huang, R., & Zbiek, R. M. (2016). Prospective Secondary Mathematics Teacher Preparation and Technology. In *The Mathematics Education of Prospective Secondary Teachers Around the World* (17-23). Springer, Cham.

International Society for Technology in Education (2017). ISTE standards for educators. Retrieved 21.02. 2018, from https://www.iste.org/standards/for-educators.

International Society for Technology in Education (2008). ISTE standards teachers. Retrieved 05.08.2017, from https://www.iste.org/docs/pdfs/20-14_ISTE_Standards-T_PDF.pdf

Jaipal, K. & Figg, C. (2015). The Framework of TPACK-in-Practice: Designing Content-Centric Technology Professional Learning Contexts to Develop Teacher Knowledge of Technology-enhanced Teaching (TPACK). In *Technological pedagogical content knowledge* (137-163). Springer US.

Jang, S. J. (2008b). Innovations in science teacher education: effects of integrating technology and team-teaching strategies. *Computers & Education, 51,* 646–659.

Jen, T. H., Yeh, Y. F., Hsu, Y. S., Wu, H. K., & Chen, K. M. (2016). Science teachers' TPACK-Practical: Standard-setting using an evidence-based approach. *Computers & Education*, *95*, 45-62.

Harris J. & Hofer M. (2009) Instructional planning activity types as vehicles for curriculum-based TPACK development. *In Research Highlights in Technology and Teacher Education 2009* (ed. C.D. Maddux), pp. 99-108. Society for Information Technology in Teacher Education (SITE), Chesapeake,VA.

Harris, J., Grandgenett, N., & Hofer, M. (2010, March). Testing a TPACK-based technology integration assessment rubric. In *Society for Information Technology & Teacher Education International Conference* (3833-3840). Association for the Advancement of Computing in Education (AACE).

Harris J., Mishra P. & Koehler M. J. (2009). Teachers' Technological Pedagogical Content Knowledge and learning activity types: curriculum-based technology integration reframed. *Journal of Research on Technology in Education, 41*, 393 – 416.

Hewitt, J. (2008). Reviewing the handbook of technological pedagogical content knowledge (TPCK) for educators. *Canadian Journal of Science, Mathematics, and Technology Education, 8*(4), 355-360.

Hofer, M., & Grandgenett, N. (2012). TPACK development in teacher education: A longitudinal study of pre-service teachers in a secondary M.A.Ed.

program. *Journal of Research on Technology in Education, 45*(1), 83-106.

Hofer M. & Harris J. (2010). Differentiating TPACK development: using learning activity types with inservice and preservice teachers. In Proceedings of *Society for Information Technology & Teacher Education International Conference* (eds D. Gibson & B. Dodge), 3857-3864. AACE, Chesapeake, VA.

Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers professional development. *Computers & Education*, *55*(3), 1259-1269.

Kabakci-Yurdakul, I., Odabasi, H. F., Kilicer, K., Coklar, A. N., Birinci, G., & Kurt, A. A. (2012). The development, validity and reliability of TPACK-deep: A technological pedagogical content knowledge scale. *Computers & Education*, *58*(3), 964-977.

Kaufman, K. (2015). Information communication technology: challenges & some prospects from preservice education to the classroom. *Mid-Atlantic Education Review, 2*(1), 1-11.

Kavanoz, S., Yüksel, H. G., & Özcan, E. (2015). Pre-service teachers' self-efficacy perceptions on Web Pedagogical Content Knowledge. *Computers & Education*, *85*, 94-101.

FATIH (2018, January 20). Movement of enhancing opportunities and improving technology project web site. Retrieved 11.2.2018 from http://fatihprojesi.meb.gov.tr/

Fraenkel, J. R., & Wallen, N. E.(2006). *How to design and evaluate research in education* (6th ed.). Boston: McGraw-Hill.

Koehler M. J. & Mishra P. (2005). What happens when teachers design educational technology? The development of Technological Pedagogical Content Knowledge. *Journal of Educational Computing Research, 32*, 131–152.

Koehler, M. J. & Mishra, P. (2008). Introducing TPCK. In *Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators* (ed. AACTE Committee on Innovation and Technology), pp. 3–29. NY: Routledge.

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education,* *9*(1), 60-70.

Koehler, M. J., Mishra, P., Bouck, E. C., DeSchryver, M., Kereluik, K., Shin, T. S., & Wolf, L. G. (2011). Deep-play: Developing TPACK for 21st century teachers. *International Journal of Learning Technology, 6*(2), 146-163.

Koehler, M. J., Mishra, P. & Yahya, K. (2007). Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology. *Computers & Education, 49*(3), 740–762.

Koehler, M. J., Shin, T. S., & Mishra, P. (2012). How do we measure TPACK? Let me count the ways. In *Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches* (16-31). IGI Global.

Koh, J. H. L., Chai, C. S., & Tsai, C. C. (2010). Examining the technological pedagogical content knowledge of Singapore pre-service teachers with a large-scale survey. *Journal of Computer Assisted Learning*, *26*(6), 563-573.

Koh, J. L., & Divaharan, S. (2011). Developing pre-service teachers' technology integration expertise through the TPACK-developing instructional model. *Journal of Educational Computing Research, 44*(1), 35-58.

Kurt, G. (2016). Technological pedagogical content knowledge (TPACK) development of preservice middle school mathematics teachers in statistics teaching: A microteaching lesson study (Unpublished doctoral thesis). Middle East Technical University, Ankara, Turkey.

Lawless, K. A., & Pellegrino, J. W. (2007). Professional development in integrating technology into teaching and learning: Knowns, unknowns, and ways to pursue better questions and answers. *Review of educational research*, *77*(4), 575-614.

Lee, H. & Hollebrands, K. (2008). Preparing to teach mathematics with technology: An integrated approach to developing technological pedagogical content knowledge. *Contemporary Issues in Technology and Teacher Education*, *8*(4), 326-341.

Lee, Y., & Lee, J. (2014). Enhancing pre-service teachers' self-efficacy beliefs for technology integration through lesson planning practice. *Computers & Education, 73*, 121-128.

Lee, M. H., & Tsai, C. C. (2010). Exploring teachers’ perceived self efficacy and technological pedagogical content knowledge with respect to educational use of the World Wide Web. *Instructional Science, 38*(1), 1-21.

Liu, S. H. (2016). Teacher education programs, field-based practicums, and psychological factors of the implementation of technology by pre-service teachers. *Australasian Journal of Educational Technology*, *32*(3).

Lyublinskaya, I. & Tournaki, E. (2011) The effects of teaching and learning with Texas Instruments handheld devices on student achievement in algebra. *Journal of Computers in Mathematics and Science Teaching, 30*(1), 5-35.

Meagher, M., Ozgun-Koca, A., & Edwards, M. T. (2011). Pre-service teachers' experiences with advanced digital technologies: The interplay between technology in a pre-service classroom and in field placements. *Contemporary Issues in Technology and Teacher Education*, *11*(3), 243-270. Retrieved September 10, 2017 from https://www.learntechlib.org/p/36172/

Meng, C. C., & Sam, L. C. (2013). Developing Pre-Service Teachers' Technological Pedagogical Content Knowledge for Teaching Mathematics with the Geometer's Sketchpad through Lesson Study. *Journal of Education and Learning, 2*(1), 1-8.

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. San Francisco, CA: Jossey-Bass.

Ministry of National Education (2013). Ortaokul matematik dersi öğretim programı 5-8. sınıflar. Ankara, Turkey: MoNE.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers college record, 108*(6), 1017-1054.

Mishra, P., & Koehler, M. J. (2008, March). Introducing technological pedagogical content knowledge. In *annual meeting of the American Educational Research Association* (pp. 1-16).

Mishra, P., Koehler, M. J., & Kereluik, K. (2009). The song remains the same: looking back to the future of educational technology. *TechTrends, 53* (5), 48–53.

Mouza, C., Karchmer-Klein, R., Nandakumar, R., Ozden, S. Y., & Hu, L. (2014). Investigating the impact of an integrated approach to the development of preservice teachers' technological pedagogical content knowledge (TPACK). *Computers & Education*, *71*, 206-221.

Mouza, C., & Karchmer-Klein, R. (2013). Promoting and assessing pre-service teachers' technological pedagogical content knowledge (TPACK) in the context of case development. *Journal of Educational Computing Research*, *48*(2), 127-152.

Mouza, C., Nandakumar, R., Yilmaz Ozden, S., & Karchmer-Klein, R. (2017). A Longitudinal Examination of Preservice Teachers' Technological Pedagogical Content Knowledge in the Context of Undergraduate Teacher Education. *Action in Teacher Education*, *39*(2), 153-171.

Mudzimiri, R. (2012). *A study of the development of Technological Pedagogical Content Knowledge (TPACK) in pre-service secondary mathematics teachers* (Unpublished Doctoral Thesis). Montana State University, USA.

National Council of Teachers of Mathematics (2014). *Principles to actions: Ensuring mathematical success for all*. Reston, VA: Author.

National Research Council (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Washington, DC: National Academics Press.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and teacher education*, *21*(5), 509-523.

Niess, M. L. (2006). Guest Editorial: Preparing teachers to teach mathematics with technology. *Contemporary Issues in Technology and Teacher Education*, *6*(2), 195-203.

Niess, M. (2008, March). Mathematics teachers developing technology, pedagogy and content knowledge (TPACK). In *Society for Information Technology & Teacher Education International Conference* (5297-5304). Association for the Advancement of Computing in Education (AACE).

Niess, M. L. (2011). Investigating TPACK: Knowledge growth in teaching with technology. *Journal of Educational Computing Research*, *44*(3), 299-317.

Niess, M. L. (2012). Rethinking pre-service mathematics teachers' preparation: technological, pedagogical and content knowledge (TPACK). D. Polly, C. Mims, K. Persichitte (Eds.), Developing technology-rich, teacher education programs: Key issues, IGI Global, Hershey, PA (2012), 316-336.

Niess, M. L., Ronau, R. N., Shafer, K. G., Driskell, S. O., Harper, S. R., Johnston, C., Browning, C., Ozgun-Koca, S. A., & Kersaint, G. (2009). Mathematics teacher TPACK standards and development model. *Contemporary Issues in Technology and Teacher Education*, *9*(1), 4-24.

Niess, M. L., Sadri, P., & Lee, K. (2007). Dynamic spreadsheets as learning technology tools: Developing teachers' technology pedagogical content knowledge (TPCK). *American Educational Research Association*.

OECD. (2010). *Inspired by technology, driven by pedagogy: A systemic approach to technology-based school innovations.* Paris: OECD Publishing.

Oksuz, C., Serife, A. K., & Uca, S. (2009). A perception scale for technology use in the teaching of elementary mathematics. *Yuzuncu Yil University Faculty of Education Journal*, *6*(1), 270-287.

Ozgun-Koca, S. A., Meagher, M., & Edwards, M. T. (2010). Preservice teachers' emerging TPACK in a technology-rich methods class. *Mathematics Educator*, *19*(2), 10-20.

Ozgun-Koca, S. A., Meagher, M., & Edwards, M. T. (2011). A teacher's journey with a new generation handheld: Decisions, struggles, and accomplishments. *School Science and Mathematics*, *111*(5), 209-224.

Papert, S. (1997). A critique of technocentrism in thinking about the school of the future. In Sendov, B. & Stanchev, I. (Eds.), *Children in the information age: Opportunities for creativity, innovation, and new activities* (pp. 3-18). Oxford: Pergamon Press.

Patton, M. Q. (1999). On enhancing the quality and credibility of qualitative analysis. *Health Services Research, 34*(5), 1189-1208.

Patton, M. Q. (2002). *Qualitative research and evaluation methods.* Thousand Oaks, CA: Sage Publications.

Polly, D., Mims, C., Shepherd, C. E., & Inan, F. (2010). Evidence of impact: Transforming teacher education with preparing tomorrow's teachers to teach with technology (PT3) grants. *Teaching and Teacher Education*, *26*(4), 863-870.

Prensky, M. (2001). Digital natives, digital immigrants part 1. *On the Horizon*, *9*(5), 1–6.

Richardson, K. W. (2010). TPACK: Game on. *Learning and Leading with Technology*, *37*(8), 34-35. Retrieved from http://leadinginnovation11t.wikispaces.com/file/view/TPACK+game+on.pdf

Rittel.H., & Webber, M., (1973).Dilemmas in a general theory of planning, *Policy Sciences*, *4*(2), 155-169.

Rogers, E. M. (1995). Diffusion of innovations. New York, Free Press.

Sang, G., Valcke, M., Van Braak, J., & Tondeur, J. (2010). Student teachers' thinking processes and ICT integration: Predictors of prospective teaching behaviors with educational technology. *Computers & Education*, *54*(1), 103-112.

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological Pedagogical Content Knowledge (TPCK): The development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, *42*(2), 27.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1-22.

So, H. J., & Kim, B. (2009). Learning about problem based learning: Student teachers integrating technology, pedagogy and content knowledge. *Australasian Journal of Educational Technology*, *25*(1), 101-116.

Thompson, A. D., & Mishra, P. (2007). Editors' Remarks: Breaking News: TPCK Becomes TPACK!. *Journal of Computing in Teacher Education*, *24*(2), 38-64.

Tondeur, J., van Braak, J., Sang, G., Voogt, J., Fisser, P., & Ottenbreit-Leftwich, A. (2012). Preparing pre-service teachers to integrate technology in education: A synthesis of qualitative evidence. *Computers & Education*, *59*(1), 134-144.

Tondeur, J., Roblin, N. P., van Braak, J., Fisser, P., & Voogt, J. (2013). Technological pedagogical content knowledge in teacher education: In search of a new curriculum. *Educational Studies*, *39*(2), 239-243.

Tondeur, J., Roblin, N. P., van Braak, J., Voogt, J., & Prestridge, S. (2017). Preparing beginning teachers for technology integration in education: Ready for take-off? *Technology, Pedagog and Education*, *26*(2), 157-177.

Tondeur, J., Scherer, R., Siddiq, F., & Baran, E. (2017). A comprehensive investigation of TPACK within pre-service teachers\u2019 ICT profiles: Mind the gap!. *Australasian Journal of Educational Technology*, *33*(3).

Tondeur, J., van Braak, J., Siddiq, F., & Scherer, R. (2016). Time for a new approach to prepare future teachers for educational technology use: Its meaning and measurement. *Computers & Education*, *94*, 134-150.

Voogt, J., Fisser, P., Tondeur, J., & van Braak, J. (2016). Using theoretical perspectives in developing understanding of TPACK. In M. C. Heering, M. J. Koehler, & P. Mishra (Eds.), *Handbook of technological pedagogical and content knowledge (TPACK) for educators* (2nd ed., pp. 33-52). NY: Routledge.

Voogt, J., Fisser, P., Pareja-Roblin, N., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge–a review of the literature. *Journal of computer assisted learning*, *29*(2), 109-121.

Yin, R. K. (2013). *Case study research: Design and methods* (4th ed.). Thousand Oaks, CA: Sage.

Yin, R. K. (2009). Case Study Research: Design and Methods. Essential guide to qualitative methods in organizational research (Vol. 5). In *The Information Systems Research Challenge (Harvard Business School Research Colloquium). London: Sage*.

Yin, R. K. (2003). *Case study research: Design and methods*. *Sage.*

Yigit, M. (2014). A Review of the literature: How pre-service mathematics teachers develop their technological, pedagogical, and content knowledge. *Online Submission*, *2*(1), 26-35.

Yeh, Y. F., Hsu, Y. S., Wu, H. K., Hwang, F. K., & Lin, T. C. (2014). Developing and validating technological pedagogical content knowledge-practical (TPACK-practical) through the Delphi survey technique. *British Journal of*

Educational Technology, *45*(4), 707-722.

Yeh, Y. F., Chien, S. P., Wu, H. K., & Hsu, Y. S. (2015). Rubrics of TPACK-P for teaching science with ICTs. In *Development of Science Teachers' TPACK* (53-70). Singapore: Springer.

Yeh, Y. F., Hwang, F. K., & Hsu, Y. S. (2015). Applying TPACK-P to a teacher education program. In *Development of Science Teachers' TPACK* (71-88). Springer Singapore.

Yeh, Y. F., Lin, T. C., Hsu, Y. S., Wu, H. K., & Hwang, F. K. (2015). Science teachers' proficiency levels and patterns of TPACK in a practical context. *Journal of Science Education and Technology*, *24*(1), 78-90.

Yeh, Y. F., Hsu, Y. S., Wu, H. K., & Chien, S. P. (2017). Exploring the structure of TPACK with video-embedded and discipline-focused assessments. *Computers & Education*, *104*, 49-64.

Zelkowski, J. (2011a). Developing Secondary Mathematics Preservice Teachers' Technological Pedagogical and Content Knowledge: Influencing Positive Growth. In M. Koehler & P. Mishra (Eds.), *Proceedings of SITE 2011--Society for Information Technology & Teacher Education International Conference* (pp. 4443-4450). Nashville, Tennessee, USA: Association for the Advancement of Computing in Education (AACE). Retrieved June 10, 2018 from https://www.learntechlib.org/primary/p/37032/

APPENDICES

APPENDIX A: THE LIST OF COURSES IN ELEMENTARY MATHEMATICS EDUCATION PROGRAM

University Compulsory Courses		T	P	C	ECTS
BTU100	COMPUTER LITERACY	2	-	2	2
ORY100	INTRODUCTION TO UNIVERSITY LIFE	1	-	1	1

First Term (Fall)		T	P	C	ECTS
ATA101	ATATURK'S PRIN. AND THE HIST. OF THE TURKISH REP. I	2	-	2	2
EĞT141	INTRODUCTION TO EDUCATION SCIENCES	3	-	3	4
ENG125	ENGLISH I	4	-	4	5
GNK103	COMPUTER SKILLS I	2	2	3	5
MTE101	FUNDAMENTALS OF MATHEMATICS	4	2	5	12
TÜRK103	TURKISH I: WRITTEN COMMUNICATION	2	-	2	2

Second Term (Spring)		T	P	C	ECTS
ATA102	ATATURK'S PRIN. AND THE HIST. OF THE TURKISH REP. II	2	-	2	2
EĞT142	EDUCATIONAL PSYCHOLOGY	3	-	3	4
ENG126	ENGLISH II	4	-	4	5
GNK104	COMPUTER SKILLS	2	2	3	5
MTE102	ABSTRACT MATHEMATICS	3	-	3	6

MTE104	GEOMETRY	3	-	3	6
TÜRK104	TURKISH II: ORAL COMMUNICATION	2	-	2	2

Third Term (Fall)		T	P	C	ECTS
EĞT241	PRINCIPLES AND METHODS OF INSTRUCTION	3	-	3	4
ENG225	ENGLISH III	4	-	4	5
GNK255	RESEARCH METHODS	2	-	2	3
MTEXXX	DEPARTMENTAL ELECTIVE I	2	-	2	4
MTE203	LINEAR ALGEBRA I	3	-	3	4
MTE205	PHYSICS I	4	-	4	4
MTE213	ANALYSIS I	4	2	5	6

Fourth Term (Spring)		T	P	C	ECTS
EĞT242	EDUCATIONAL TECHNOLOGY AND MATERIAL DESIGN	2	2	3	4
ENG226	ENGLISH IV	4	-	4	5
GNKXXX	CULTURAL ELECTIVE V	3	-	3	4
MTE206	PHYSICS II	4	-	4	4
MTE212	ANALYSIS II	4	2	5	8
MTE214	LINEAR ALGEBRA II	3	-	3	5

Fifth Term (Fall)		T	P	C	ECTS
EĞTXXX	EDUCATIONAL ELECTIVE III	2	-	2	3
EĞT347	METHODOLOGY I	2	2	3	4
GNKXXX	CULTURAL ELECTIVE I	3	-	3	5
GNK301	HISTORY OF SCIENCES	2	-	2	3
MTE301	ANALYSIS III	3	-	3	5
MTE303	ANALYTIC GEOMETRY I	3	-	3	3
MTE305	STATISTICS AND PROBABILITY I	2	2	3	4

MTE307	INTRODUCTION TO ALGEBRA	3	-	3	3

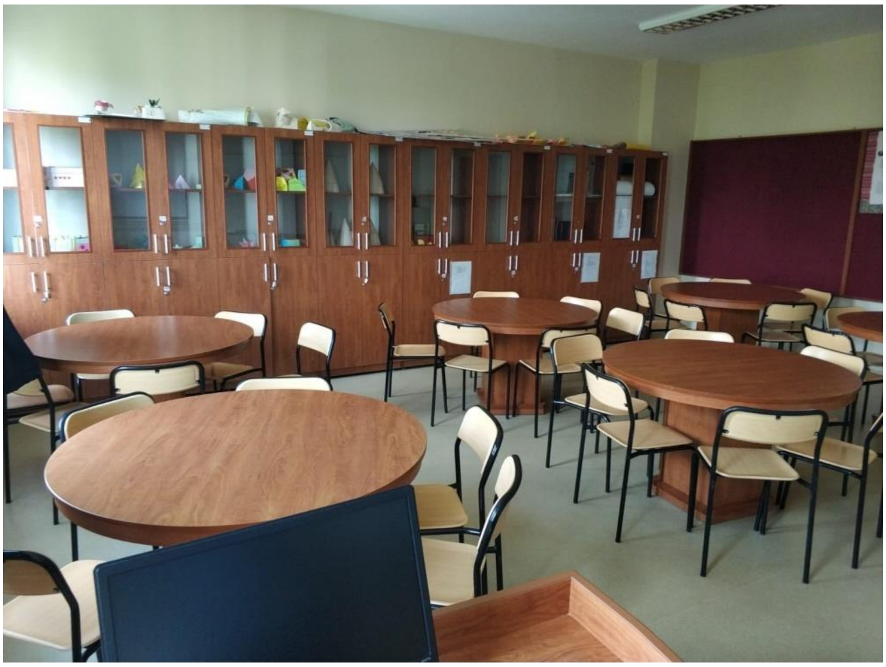
Sixth Term (Spring)		T	P	C	ECTS
EĞT346	MEASUREMENT AND EVALUATION	3	-	3	4
GNKXXX	CULTURAL ELECTIVE II	3	-	3	5
GNK302	COMMUNITY SERVICE	1	2	2	4
GNK392	ORIGAMI	2	-	2	3
MTE302	DIFFERENTIAL EQUATIONS	4	-	4	4
MTE312	COMPLEX ANALYSIS	2	2	3	3
MTE314	METHODOLOGY II	2	2	3	4
MTE316	ANALITIK GEOMETRI II	3	-	3	3

Seventh Term (Fall)		T	P	C	ECTS
EĞT403	GUIDANCE	3	-	3	4
EĞT441	SPECIAL EDUCATION	2	-	2	4
EĞT443	CLASSROOM MANAGEMENT	2	-	2	4
EĞT449	SCHOOL EXPERIENCE	1	4	3	8
GNK405	HISTORY OF MATHEMATICS	2	-	2	2
MTEXXX	DEPARTMENTAL ELECTIVE II	3	-	3	4
MTE407	ELEMENTRY NUMBER THROY	3	-	3	4

Eighth Term (Spring)		T	P	C	ECTS
EĞTXXX	EDUCATIONAL ELECTIVE II	3	-	3	4
EĞT406	TEACHING PRACTICE	2	6	5	9
EĞT448	TURKISH EDUCATION SYSTEM AND SCHOOL ADMINISTRATION	2	-	2	4
GNKXXX	CULTURAL ELECTIVE VI	3	-	3	5
MTE406	BASIC MATHEMATICAL CONSEPTS	2	-	2	8

T: Theory, P: Practice, C: Credit, ECTS: European Credit Transfer System

APPENDIX B: THE SETTING OF THE TUME COURSE: THE MATHEMATICS LABORATORY



APPENDIX C: TECHNOLOGY USE IN MATHEMATICS EDUCATION COURSE SYLLABUS

XXX ÜNİVERSİTESİ EĞİTİM FAKÜLTESİ

DERS BİLGİLERİ	Matematik Eğitiminde Teknoloji Kullanımı (Genel Kültür Seçmeli VI / T-U-K: 3-0-3 AKTS: 5) **Gün ve saat:** Pazartesi 11:00 – 13:50 **Yer:** B307 Matematik Laboratuarı (Ders size önceden bildirilecek haftalarda B206 Bilgisayar Laboratuarında yapılacaktır.)
DÖNEMİ	2015-2016 Bahar Yarıyılı
DERSİN SORUMLUSU	Arş. Gör. Merve Koştur **Ofis:** A 204 **e-posta:** x@x

Derste kullanılacak teknolojiler:

Facebook ders sayfası: https://www.facebook.com/groups/baskenteknoloji/

Cep telefonunuz

Laptop, tablet ve masaüstü bilgisayar

Matematik Eğitiminde Teknoloji Kullanımı Dersi Haftalık İçeriği	
TARİH	**KONU**
15 Şubat	Ders içeriği ve dersin işlenişi ile ilgili bilgi verme
22 Şubat*	Matematik eğitiminde teknoloji kullanımı Eğitim teknolojisi nedir? FATIH projesi
29 Şubat*	Teknolojik Pedagojik Alan Bilgisi (TPAB) nedir? TPAB araştırmaları
7 Mart	Mobil öğrenme Öğretmenlerin sosyal paylaşım ağları Görsel paylaşım siteleri ETKİNLİK 1: Matematik aktivelerini keşfedelim!
14 Mart	Sınav ve puzzle hazırlama programları Kavram haritası ve poster hazırlama programları Zaman çizelgesi hazırlama programı ETKİNLİK 2: Kavram haritalarını keşfedelim! ETKİNLİK 3: Eğitici posterler hazırlama
21 Mart	Dinamik Matematik programları Açık eğitim materyalleri ETKİNLİK 4: Matematiğin İnşası
28 Mart	Teknolojinin öğretimin değerlendirilmesindeki rolü Öğrenci dönüt sistemleri ETKİNLİK 5: Öğrenmeyi değerlendirme
4 Nisan (Vize haftası)	ETKİNLİK 6: Akıllı tahtaları keşfetme
11 Nisan	Video hazırlama programları ETKİNLİK 7: Vlogger video çekimi
18 Nisan	Interaktif matematik manipülatifleri ve oyunları ETKİNLİK 8: İnteraktif oyun yarışması

25 Nisan	ETKİNLİK 9: TPACK oyunu ile ders planları hazırlama Matematik ve diğer alanlarda teknoloji entegre edilmiş ders planı örnekleri incelenmesi
2 Mayıs	Mikro-öğretim
9 Mayıs	Mikro-öğretim
16 Mayıs	Mikro-öğretim

*İlgili kaynaklar

Akyüz, D. (2014). Çember özelliklerini öğretmeyi amaçlayan teknoloji ve sorgulama tabanlı bir sınıfta oluşan sosyomatematiksel normların incelenmesi. *Eğitim ve Bilim*, *39*(175), 58-72. doi:10.15390/EB.2014.3220

Pamuk, S., Çakır, R., Ergun, M., Yilmaz, H. B., & Ayas, C. (2013). Öğretmen ve Öğrenci Bakış Açısıyla Tablet PC ve Etkileşimli Tahta Kullanımı: FATIH Projesi Değerlendirmesi. *Kuram ve Uygulamada Eğitim Bilimleri, 13*(3), 1799-1822.

Ural, A. (2015). Ortaokul Matematik Öğretmenlerinin Bilgi İletişim Teknolojisi ve Psikomotor Beceri Kullanımlarının İncelenmesi. *Turkish Journal of Computer and Mathematics Education, 6*(1),93-116.

Van de Walle, J.A., Karp, K. S. & Bay-Williams, J. M. (2013). *Elementary and middle school mathematics: Teaching developmentally* (8thed.). New York: Longman.

Yanpar Yelken, T., Sancar Tokmak, H., Özgelen, S. ve İncikabı, L. (2013). *Fen ve matematik eğitiminde teknolojik pedagojik alan bilgisi temelli öğretim tasarımları* (1. bs.). Ankara: Anı Yayıncılık.

GÖREVLER

A. Ders planı (Dönem başı) (% 10)

Ortaokul müfredatından en az iki ders saatlik kazanım(lar) seçerek teknoloji entegre ettiğiniz bir ders planı hazırlayınız. Bu planı ikinci hafta yapılacak teorik dersten önce moodle sistemine yükleyiniz.

B. Haber ve soru paylaşımı (% 10)

Size belirtilen haftalarda Facebook ders sayfasında o haftanın konusuyla ilgili bilgi paylaşınız. Bu bilgi gazete haberi, video, forum paylaşımı, blog yazısı, kitap, makale, tweet, vb. olabilir.

C. Katılım (% 20)

Sınıf içi ve online aktivitelere ve tartışmalara aktif katılım sağlamanız beklenmektedir. Dersteki 9 etkinlikte oluşturduğunuz grup veya bireysel ürünlerinizi Facebook ders sayfasında paylaşmanız ve arkadaşlarınızın veya grupların en az iki paylaşımına yorum yapmanız beklenmektedir.

D. Haftalık Değerlendirme (%10)

Size belirtilen 5 haftada dersin son 10 dakikasında "haftalık değerlendirme" sorularına o hafta derste yaptıklarınızla ilgili bir değerlendirme yazınız. Bu değerlendirmenizi e-posta veya mesaj ile iletiniz.

E. VİZE: Ders planı (%20)

Ortaokul (5-8. sınıflar) müfredatından iki ders saatlik konu (dönemin başında seçilen konudan farklı) seçerek teknoloji entegre ettiğiniz bir ders planı hazırlayınız ve teorik dersten önce moodle sistemine yükleyiniz.

F. FİNAL: Ders anlatımı (Sınıf içi mikro-öğretim) (% 30)

Vize için hazırladığınız ders planınızı sınıfımızda arkadaşlarınıza anlatmanız beklenmektedir.

APPENDIX D: VLOGGER VIDEO ACTIVITY

Vlogger Etkinliği

Son 1 yıldır etkinliklerini, materyallerini ve deneyimlerini videolar ile paylaşan ve çok takip edilen bir Vlogger oldunuz. Türkiye'de ve dünyada matematik etkinliklerindeki yaratıcılığıyla, matematik bilgisiyle ve öğretmenlik mesleğindeki başarısıyla fenomen olmuş bir 21. yüzyıl öğretmenisiniz. Bugün, Başkent Kolejindeki ortaokul matematik öğretmenlerinden gelen sorulara çözüm bulacak ve cevaplarınızı bir video ile sosyal medyada duyuracaksınız. Bu videoların çekimi için derste 2 kişilik gruplar halinde çalışacaksınız. Öğretmenler yaşadıkları zorluklar için yaratıcı fikirlerinizi bekliyor!

İpuçları:

Bu matematik konusunun müfredattaki kazanımları neler?

Önceki ve sonraki bağlantılı olduğu konuları düşünün.

Ders planı basamaklarını hatırlayın.

Pedagojik yaklaşım ne olmalı?

Teknolojik destek ne olmalı?

Sorulara dönüt verirken dikkat ettiğiniz maddeler var. Bunlar sizin öğretim prensipleriniz. Cevaplarınızı hazırlarken her zaman bu prensipleri göz önüne alarak hazırlanıyorsunuz.

- Sınıfların kalabalık oluşu, matematik öğretiminin gerçekleşmesini zorlaştırmaktadır.
- Kavramlar öğretilirken, öğrencilerin yaşadığı çevreden örnekler verilip, günlük hayatla ilişkilendirilmelidir.
- Sınıftaki öğrencilerin öğrenme düzeyleri homojen olmadığı için, istenilen nitelikte matematik öğretimi yapılamamaktadır. Bu nedenle, her öğrencinin bireysel ihtiyacına ve öğrenme şekline yönelik çeşitli aktivitelere yer

verilmelidir.

- Öğretmenlerimizin işlenilen müfredattaki kazanımları takip etmesi ve soruları öğretilen konular çerçevesinde sorması gerekmektedir.
- Öğretmenlerin anlattıkları konular içerisinde, sordukları soruları kendilerinin çözmemesi, öğrencilere çözdürmesi ve onların sorular üzerindeki düşüncelerini alması, problem çözümünde nerelerde hata yapıyorlarsa, oralarda öğrencilere yardımcı olması kavram ve konu öğreniminde yararlı olmaktadır.
- Matematik öğretiminde sadece işlemsel ve kurala dayalı bilgiye önem verilmemeli, bu bilginin temelini oluşturan kavramsal bilgi üzerinde de durulmalıdır
- Matematik öğretiminde sadece tahta kullanılarak sunuş yoluyla öğretim yapılmamalıdır. Konuların özelliğine göre değişik öğretim yöntemleri ve teknoloji de kullanılmalıdır.
- Öğrencilerin matematiğe karşı ilgisini artırmak için, birbirleriyle iyi iletişim kurmaları, matematiği tartışacakları iyi bir öğrenme ortamı hazırlanmalıdır.

Öğretmen Adaylarına Verilen Senaryolar

1. Olasılık çeşitlerini ayırmada zorluk yaşıyorlar.

Kağıt üzerinde matematik sınavında başarı şansını hesaplayan Yakup konuları kavrayışına göre % 80 başarılı olacağını hesaplamıştır. Bu hangi tür olasılığa girmektedir?

A) Subjektif olasılık B) Deneysel olasılık C) Öznel olasılık D) Teorik olasılık

Permütasyon, kombinasyon ve olasılık konularını ayıramıyorlar. Bu konularda kavram yanılgısı yaşıyorlar. Ayrıca, genel olarak konular işlenirken sınıftaki bütün öğrencilerin derse katılımını sağlayamıyorum.

2. 5. sınıflarda bir öğrencim var çok zeki, 70 soruda 5-10 yanlışı çıkıyor ve bu yaptığı yanlışlar çok basit sorularda meydana geliyor. Sınavdan sonra denemesine baktığında dikkatsizliğinden soruların kaçtığını görüyor ve üzülüyor. Bu öğrencinin soruları dikkatli okuması için nasıl bir yöntem izlemeliyim. Ne gibi bir çalışma yapmalıyım?

7. Sınıflarda rasyonel sayılarla işlemler (dört işlem) konusunda öğrenciler ezber yolu ile soruları çözüyorlar. Rasyonel sayılarla bir bütün arasındaki ilişkiyi kavrayamıyorlar. Bu konuda nasıl bir yol izleyebilirim?
Ayrıca, genel olarak konular işlenirken sınıftaki bütün öğrencilerin derse katılımını sağlayamıyorum.

3. Bölünebilme kurallarını anlatırken 100 lük kağıt ve boya kalemleri dışında nasıl materyal kullanabilirim lütfen yardımcı olur musunuz?
Ayrıca, genel olarak konular işlenirken sınıftaki bütün öğrencilerin derse katılımını sağlayamıyorum.

4. Öğrenciler 7. sınıfta doğrusal denklemlerin grafikleri konusunu gerçek yaşamla bağdaştıramıyorlar. Bu durumda, test kitaplarında ve ders kitabında yer alan soruları sınıfta çözdüğümüzde ve ödev olarak verdiğimde konunun günlük yaşamda karşımıza çıkmadığını, soruların (örneğin koordinat sisteminde oluşturulan soruların) gerçekte anlam taşımadığını söylemekteler. Konuya böyle yaklaştıkları için motivasyonları düşüyor ve konuyla ilgili soruları yalnızca doğrunun denklemini bulma kurallarını uygulayarak çözüp geçiyorlar. Böyle olunca sadece kural bilerek yapılamayacak bir soruyu yanıtlamakta güçlük çekiyorlar. Kartezyen koordinat sistemini anlamlandırmakta zorlanıyorlar.
Matematik dersinde öğrenci kaynaklı olarak "sınıfta konuşma ve gülme", "derse karşı ilgisizlik" ve "dersten başarısız olma" durumu ile karşı karşıyayım. Sınıf ortamında çıkan problemlere karşı etkili olamadığımı görüyorum. Bunun nedenlerinden birisi matematik dersine karşı olan kaygı ve korku olabilir. Başarı korkusu yaşayan öğrenciler sınıfta gergin ve stresli olabilirler ve bunun sonucunda istenmeyen davranışlar ve olumsuz olaylar gelişebilir. Yapılan araştırmalarda ülkemizdeki pek çok öğrencinin matematiği zor bulduğu, başaramama kaygısı yaşadıkları ve bunların sonucunda matematiğe yönelik tutumlarının olumsuz yönde etkilenebileceği sonucuna ulaşılmıştır (Alkan, Güzel ve Elçi, 2004; MEB, 2005). Genel olarak konular işlenirken sınıftaki bütün öğrencilerin derse katılımını sağlayamıyorum.

5. Öğrenciler örüntüler konusunu gerçek yaşamla bağdaştıramıyorlar. Bu durumda test kitaplarında ve ders kitabında yer alan soruları sınıfta çözdüğümüzde ve ödev olarak verdiğimde konunun günlük yaşamda karşımıza çıkmadığını, soruların gerçekte anlam taşımadığını söylemekteler. Motivasyonları düşük bir şekilde konuyla ilgili soruları kuralları uygulayarak çözmeye çalışıyorlar. Böyle olunca sadece kural bilerek yapılamayacak bir soruyu yanıtlamakta güçlük çekiyorlar. Fraktal, yansıma, dönme konularında da aynı sorunu yaşıyorum.
Ayrıca, genel olarak konular işlenirken sınıftaki bütün öğrencilerin derse katılımını sağlayamıyorum.

6. Yaşadığım sorun 8. sınıftaki eğim konusunda. Öğrenciye tanımı veriyorum, işlemin nasıl yapılacağını söylüyorum ondan sonra örnekler yapıyorum ve ödev olarak alıştırmalar ve problemler veriyorum. Aradaki bağı kuramıyor veya kurma gereği duymuyor öğrenci; gerçekleştiremeyince de ezberleme yoluna gidiyor. Öğrenciye önceden sorular sorarak; öğrenciyi, orada ulaşılmak istenen genelleme ve ilkeleri bulmaya yönlendirip, ondan sonra kendisi çıkarım yapsın istiyorum. Öğrenciye düşünme imkanı sağlamak, kendi başına öğrenmeyi sağlamada yardımcı olmak istiyorum. Sınıfta gelişen duruma basit bir örnek vermek istiyorum: Dört işlemde, toplama, çıkarma, çarpmada belli bir yere kadar gelmiştir hatta bölmede. Öğretmen bir problem sorar ve "Hangi işlemle çözeriz bu problemi?" Toplarız öğretmenim. İyi düşün burada toplama yapılsa olur mu? Öğretmenim çıkarırız. Çocuklar aman iyi düşünün burada çıkarmayla ilgili bir şey var mı? Bir başka öğrenci öğretmenim çarparız. Oda olmadı bir başkası böleriz öğretmenim diyebilmektedir. Eğim kavramı anlaşılmıyor ve soru çözümlerinde aynen böyle bir durum yaşıyorum.
Ayrıca, genel olarak konular işlenirken sınıftaki bütün öğrencilerin derse katılımını sağlayamıyorum.

7. Öğrenciler denklemler konusunu gerçek yaşamla bağdaştıramıyorlar. Bu durumda test kitaplarında ve ders kitabında yer alan soruları sınıfta çözdüğümüzde ve ödev olarak verdiğimde konunun günlük yaşamda karşımıza çıkmadığını, soruların (örneğin yaş problemleri) gerçekte anlam taşımadığını söylemekteler.

Ali ile babasının yaşları toplamı 54'dür. Ali'nin yaşı, ikisinin yaşları toplamının 1/3'ünden 3 eksiktir. Ali ve babası kaç yaşındadır?

Konuya böyle yaklaştıkları için motivasyonları düşüyor ve konuyla ilgili soruları yalnızca denklem kurma kurallarını uygulayarak çözüp geçiyorlar. Böyle olunca sadece kural bilerek yapılamayacak aşağıdaki gibi bir soruyu yanıtlamakta güçlük çekiyorlar.

Ayrıca, genel olarak konular işlenirken sınıftaki bütün öğrencilerin derse katılımını sağlayamıyorum.

8. Yaşadığım sorun EBOB ve EKOK konusunda. Öğrenciye tanımı veriyorum, işlemin nasıl yapılacağını söylüyorum ondan sonra örnekler yapıyorum ve ödev olarak alıştırmalar ve problemler veriyorum. Aradaki bağı kuramıyor veya kurma gereği duymuyor öğrenci; gerçekleştiremeyince de ezberleme yoluna gidiyor. Öğrenciye önceden sorular sorarak; öğrenciyi, orada ulaşılmak istenen genelleme ve ilkeleri bulmaya yönlendirip, ondan sonra kendisi çıkarım yapsın istiyorum. Öğrenciye düşünme imkanı sağlamak, kendi başına öğrenmeyi sağlamada yardımcı olmak istiyorum. Sınıfta gelişen duruma basit bir örnek vermek istiyorum: Dört işlemde, toplama, çıkarma, çarpmada belli bir yere kadar gelmiştir hatta bölmede. Öğretmen bir problem sorar ve "Hangi işlemle çözeriz bu problemi?" Toplarız öğretmenim. İyi düşün burada toplama yapılsa olur mu? Öğretmenim çıkarırız. Çocuklar aman iyi düşünün burada çıkarmayla ilgili bir şey var mı? Bir başka öğrenci öğretmenim çarparız. Oda olmadı bir başkası böleriz öğretmenim diyebilmektedir. EBOB ve EKOK kavramı anlaşılmıyor ve soru çözümlerinde aynen böyle bir durum yaşıyorum. Aşağıdaki gibi çözerek ve ezberleyerek yapıyorlar.

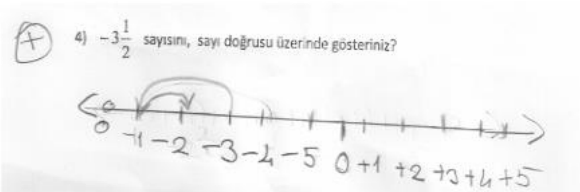
"24 ve 32'yi önce en küçük asal sayı olan 2'ye böleriz. İkisini de böldüğü için 2'yi işaretleriz. Sonra benzer şekilde devam ederiz. Her iki sayı da 1 olunca işlemimiz biter ve işaretli sayıların çarpımı bu sayıların en büyük ortak böleni yani ebobudur."

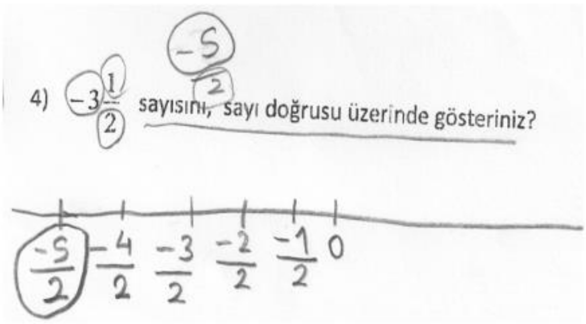
Ancak aşağıdaki gibi problem cümlesi şeklinde yazılmış soruları yapamıyorlar.

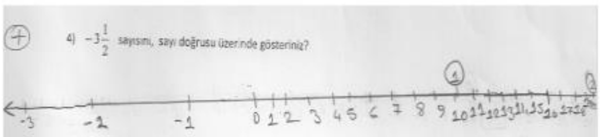
“80cm ve 120cm uzunluğunda iki demir çubuk, boyları birbirine eşit parçalara ayrılacaktır.Bir parçanın uzunluğu en fazla kaç cm olur?”
Ayrıca, genel olarak konular işlenirken sınıftaki bütün öğrencilerin derse katılımını sağlayamıyorum.

9. Merhaba, üçgenlerin sınıflandırılmasını anlatacağım. Yıllardır bu konuyu anlatıyorum ancak kenarlarına göre açılarına göre vb sınıflandırmalarda birbirinden bağımsız düşünüyorlar ve karma soruları yapamıyorlar. Öğrenciler pasif dinledikçe geleneksel onu anlatımımla sınıflandırmayı ezberletmekten ileriye gidemiyorum. Nasıl bir yol izlemeliyim? Etkili materyaller yapmak belki de öğrencilere yaptırmak gerek. Bana fikir verebilir misiniz?
Ayrıca, genel olarak konular işlenirken sınıftaki bütün öğrencilerin derse katılımını sağlayamıyorum.

10. $-2\frac{1}{3}$ sayısını, sayı doğrusu üzerinde gösteriniz?
Bu soruya öğrencilerin %35’i doğru yanıt vermiş, diğerleri ise ya işlemleri yanlış yapmış ya da soruyu boş bırakmışlardır.







Burada öğrencilerin, rasyonel sayılarla ilgili temel işlem yapma ve denklem kurma ile ilgili becerilerinin tam olarak gelişmediği anlaşılmaktadır.

Ayrıca, genel olarak konular işlenirken sınıftaki bütün öğrencilerin derse katılımını sağlayamıyorum.

APPENDIX E: THE VIEWS ABOUT TEACHING PROFESSION QUESTIONNAIRE

Öğretmenlik Mesleğine İlişkin Görüşler Anketi

Merhaba,

Aşağıdaki soruları elinizden geldiği kadar ayrıntı vererek cevaplandırmaya çalışınız. Soruların doğru bir cevabı yoktur ve sadece sizin düşüncelerinizi öğrenmek amacıyla sorulmaktadır.

Teşekkür ederiz.

Merve KOŞTUR

1. Terzi ve yanında bir süredir çalışan çırağı arasında aşağıdaki diyalog geçer.

Çırak: Usta, dikişi öğrendim. Ben de artık usta olabilir miyim? Usta olmak için başka ne öğrenmem gerek?

Terzi: Dikişi öğrendin. Peki Mustafa beyin istediği pantolonu elde mi dikersin makineyi mi kullanırsın? Makinenin tek sıra dikişini mi çift dikişini mi tercih edersin? Tabii öncesinde kumaşı seçmen gerek. Hangi tür kumaşta hangi dikiş uygun duracak? Aman potluk yapmasın sonra tüm emeğin boşa gider. Ölçü alacaksın bir de. Ölçüden sonra hesap kitap yapıp maliyet belirleyeceksin.

Çırak: Tamam usta. Öyleyse ben şu kumaşları katlayıp raflara yerleştirmeye devam edeyim…

Terzinin çırağı ile diyaloğundan yola çıkarak bir öğretmenin sahip olması gereken bilgi ve becerilerin neler olabileceğini ve neden bu bilgi ve becerilere sahip olması gerektiğini açıklayınız.

2. Dördüncü sınıf bir öğretmen adayı olarak birinci sınıftaki öğretmen adaylarına öğretmenlik mesleğine kendilerini hazırlamaları ve yeterli hissedebilmeleri için ne tür tavsiyelerde bulunursunuz?

APPENDIX F: TECHNOLOGY USAGE QUESTIONNAIRE

Teknoloji Kullanımı Anketi

Adı Soyadı:

Yaşı:

Cinsiyet:

GNO:

İletişim (Telefon ve e-posta):

1. Kaç yıldır bilgisayar kullanıyorsunuz?

2. Bilgisayarı hangi amaçlarla kullanıyorsunuz?

3. Bugüne kadar aldığınız derslerin hangilerinde bilgisayar kullandınız?

4. Bugüne kadar aldığınız derslerin hangilerinde bilgisayar dışında teknoloji (hesap makinesi, projeksiyon aleti, akıllı tahta, vb.) kullandınız mı? Nelerdir? Bu teknolojileri hangi amaçla kullandınız?

APPENDIX G: PEER-ASSESSMENT FORM

MIKRO ÖĞRETIM AKRAN DEĞERLENDIRME FORMU	
Değerlendirmeyi yapanın adı soyadı: Mikro öğretim yapanın adı soyadı:	Tarih:

ALAN	ÖĞRETİM YÖNTEMİ	TEKNOLOJİ
Sınıf düzeyi: Konu:		

Bu mikro öğretimde,

Sizce, teknoloji destekli bu dersin **en iyi olan iki yönü** ne idi? Bu yönleri neden iyi bulduğunuzu lütfen açıklayınız:

1.

2.

Sizce, teknoloji destekli bu dersin **en zayıf iki yönü** ne idi? Bu zayıf yönleri güçlendirmesi için arkadaşınıza **önerilerinizi** lütfen yazınız.

1.

2.

Bu matematik konusunun öğretiminde kullanılan teknoloji destekli öğretim hakkında ne düşünüyorsunuz? Diğer bir deyişle, kullanılan teknoloji(ler) ile öğretim yöntemi ve kazanımların ilişkisi nasıldır?

Mikro öğretime genel olarak 10 üzerinden kaç puan verirsiniz?

APPENDIX H: SELF-ASSESSMENT FORM

MIKRO ÖĞRETIM ÖZ DEĞERLENDIRME FORMU
Mikro öğretim yapanın adı soyadı: Tarih:

ALAN	ÖĞRETİM YÖNTEMİ	TEKNOLOJİ
Sınıf düzeyi: Konu:		

Bu mikro öğretimde,

Sizce, teknoloji destekli bu dersin **en iyi olan iki yönü** ne idi? Bu yönleri neden iyi bulduğunuzu lütfen açıklayınız:

1.

2.

Sizce, teknoloji destekli bu dersin **en zayıf iki yönü** ne idi? Daha iyi nasıl olabilirdi? Bu zayıf yönleri güçlendirmek için **önerilerinizi** lütfen yazınız.

1.

2.

Bu matematik konusunun öğretiminde kullanılan teknoloji destekli öğretim hakkında ne düşünüyorsunuz? Diğer bir deyişle, kullanılan teknoloji(ler) ile öğretim yöntemi ve kazanımların ilişkisi nasıldır?

Mikro öğretiminize genel olarak 10 üzerinden kaç puan verirsiniz?

APPENDIX I: INTERVIEW PROTOCOL

(Kodu: *Görüşme Süresi:)*

Matematik Öğretiminde Teknoloji Kullanımı Görüşme Soruları

Merhaba, sonuna geldiğimiz bu dönemde (2015-2016 bahar yarıyılı) GNKXXX – Matematik Eğitiminde Teknoloji Kullanımı dersini benimle birlikte yürüttünüz. Size genel olarak matematik eğitimi ve bu dersin sonunda sunduğunuz ders planı ile ilgili sorular sormak istiyorum. Bu görüşmenin 60 dakika kadar vakit alacağını düşünüyorum. İstediğiniz zaman görüşmeyi bırakabilirsiniz. Bu görüşmede vereceğiniz bilgiler saklı kalacaktır. Hiçbir şekilde isminizle birlikte bir yerde kullanılmayacaktır. Şimdi hazırsanız görüşmeye başlayalım.

Merve KOŞTUR

1. Matematik Eğitiminde Teknoloji Kullanımı dersinde haftalık olarak neler yaptığımızdan bahseder misin?
2. Derste öğrendiğin teknolojileri kullanabilmek için gerekli teknik beceriye sahip misiniz? İleride yeni karşılaşacağın bir teknolojiyi kullanabilir misin?
3. Ortaokul matematik öğretiminde teknoloji kullanmanın amacı nedir?
4. İkinci ders planı ve mikro-öğretimin ile ilgili sorular
   (Bu sorular sorulmadan önce öğrencinin ders planı öğrenciye gösterilir, ardından mikro-öğretim videosu izlenerek çalışmasını hatırlaması sağlanır.)
   a. Öğreteceğin konuyu, nasıl öğreteceğini ve öğrencilerin öğrenmesini destekleyen ve artıran teknolojiyi nasıl belirdin?
   b. Bu ders planında teknolojinin rolü nedir? Teknolojiyi neden ve nasıl entegre ettin?
   c. Bu ders planınızda teknolojiyi kullandığınız için öğretim yönteminizde değişiklik yaptın mı?
   d. Mikro-öğretim videonu izledikten sonra bu ders için görüşlerin nelerdir? Neleri değiştirirdin? Neler aynı kalırdı? Neden?
   e. Ders planında kullandığın teknolojiyi kullanma imkanın olmasaydı bu derste ne eksik olurdu? Neyi yapamazdın?
   f. Akran değerlendirmelerinin her birini sesli olarak okuyup görüşünü belirtir misin?
5. Tüm bu konuştuklarımızdan sonra teknolojinin matematik eğitiminde nasıl kullanılmasını önerirsin?
6. İleride çalıştığın okullardaki diğer matematik öğretmenlerine derslerine teknoloji entegre etmek isterlerse destekler misin? Onlara bu konuda liderlik edebilir misin?
7. Üzerinde konuşmadığımız, ama sormamı beklediğin ve sormadığım bir soru var mı? Şimdi sorsam cevaplar mısın?

APPENDIX J: ETHICAL COMMETTEE APPROVAL

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

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www.ueam.metu.edu.tr

21 TEMMUZ 2016

Sayı: 28620816 /314

Konu: Değerlendirme Sonucu

Gönderilen: Doç.Dr. Çiğdem HASER

İlköğretim Bölümü

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Doç.Dr. Çiğdem HASER;

Danışmanlığını yaptığınız doktora öğrencisi Merve KOŞTUR' un "Ortaokul Matematik Öğretmen Adaylarının Teknolojik Pedagojik Alan Bilgisi Gelişimlerinin İncelenmesi" başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2016-EGT-117** protokol numarası ile **29.07.2016-10.07.2017** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımızla sunarız.

Prof. Dr. Canan SÜMER

İnsan Araştırmaları Etik Kurulu Başkanı

Prof. Dr. Meliha ALTUNIŞIK

İAEK Üyesi

Prof. Dr. Ayhan SOL

İAEK Üyesi

Prof. Dr. Mehmet UTKU

İAEK Üyesi

Prof. Dr. Ayhan Gürbüz DEMİR

İAEK Üyesi

Yrd .Doç .Dr. Pınar KAYGAN

İAEK Üyesi

Yrd. Doç. Dr. Emre SELÇUK

İAEK Üyesi

BU BÖLÜM, İLGİLİ BÖLÜMLERİ TEMSİL EDEN İNSAN ARAŞTIRMALARI ETİK ALT KURULU TARAFINDAN DOLDURULACAKTIR.

Protokol No: 2016-EGT-117

İAEK DEĞERLENDİRME SONUCU

Sayın Hakem,

Aşağıda yer alan üç seçenekten birini işaretleyerek değerlendirmenizi tamamlayınız. Lütfen "<u>Revizyon Gereklidir</u>" ve "<u>Ret</u>" değerlendirmeleri için gerekli açıklamaları yapınız.

Değerlendirme Tarihi: 29-06-2016

Ad Soyad: Metin girmek için tıklayın

☒ **Herhangi bir değişikliğe gerek yoktur. Veri toplama/uygulama başlatılabilir.**

☐ **Revizyon gereklidir**

- ☐ Gönüllü Katılım Formu yoktur.
- ☐ Gönüllü Katılım Formu eksiktir.
  - Gerekçenizi ayrıntılı olarak açıklayınız:
- ☐ Katılım Sonrası Bilgilendirme Formu yoktur.
- ☐ Katılım Sonrası Bilgilendirme Formu eksiktir.
  - Gerekçenizi ayrıntılı olarak açıklayınız:
- ☐ Rahatsızlık kaynağı olabilecek sorular/maddeler ya da prosedürler içerilmektedir.
  - Gerekçenizi ayrıntılı olarak açıklayınız:
- ☐ Diğer.
  - Gerekçenizi ayrıntılı olarak açıklayınız:

☐ **Ret**

Ret gerekçenizi ayrıntılı olarak açıklayınız:

APPENDIX K: CONSENT FORM

Gönüllü Katılım Formu

Merhaba,

Ben Merve Koştur, Başkent Üniversitesi Eğitim Fakültesi İlköğretim Bölümü'ndeİlköğretim Matematik Eğitimi Ana Bilim Dalında araştırma görevlisiyim. Orta Doğu Teknik Üniversitesi (ODTÜ) Sosyal Bilimler Enstitüsü İlköğretim Doktora Programında öğrenciyim. İlköğretim Bölümünde Doç. Dr. Çiğdem Haser tarafından danışmanlığı yürütülen doktora tez çalışmam kapsamında sizinle görüşmek istiyorum. Bu çalışmanın amacı, ilköğretim matematik öğretmen adaylarının üniversite eğitimlerinin 8. yarıyılında aldıkları,matematik eğitiminde teknoloji kullanımı ile ilgili seçmeli derste teknolojik pedagojik alan bilgilerinin gelişimi ve matematik eğitiminde teknoloji kullanımı ile ilgili görüşlerini incelemektir. Çalışmadan elde edilen sonuçların öğretmen eğitimi konusunda yararlar sağlaması beklenmektedir.

Çalışmada dersi iyileştirmek amacıyla bir takım etkinlikler uygulanmıştır. Bu etkinliklerin uygulandığı ders sürecinde katılımcılar tarafından yazılan raporlar çalışma için kullanılacaktır. Bu çalışma kapsamında her katılımcı ile bir defaya mahsus olmak üzere sözlü görüşme yapmayı planlıyorum. Etkinlikler ve görüşme genel olarak kişisel rahatsızlık verecek sorular içermemektedir. Görüşme sırasında ses kaydı yapılacaktır. Çalışma süresince sizden edinilen bilgiler tamamen gizli tutulacak; sadece araştırmacılar tarafından değerlendirilecektir.

Çalışmaya katılım tamamen gönüllülük esasına dayalıdır. Katılımcı, görüşme esnasında sorulardan ya da başka nedenlerden dolayı herhangi bir rahatsızlık hissettiği takdirde çalışmayı yarıda bırakma hakkına sahiptir. Çalışma hakkında daha fazla bilgi almak için araştırma görevlisi Merve Koştur (Oda: A-204; Tel: 2466666/2227; E-posta:mkaplan@baskent.edu.tr) ya da İlköğretim

Bölümü öğretim üyelerinden Doç. Dr. Çiğdem Haser (Oda: 105; Tel: 210 6415; E-posta:chaser@metu.edu.tr) ile iletişim kurabilirsiniz.

Teşekkürler.

Bu çalışmaya tamamen gönüllü olarak katılıyorum ve istediğim zaman yarıda kesip çıkabileceğimi biliyorum. Verdiğim bilgilerin bilimsel amaçlı yayınlarda kullanılmasını kabul ediyorum.

Ad Soyad: ______________________ İmza: _______________________

Tarih : _______________________

APPENDIX L: INITIAL LESSON PLAN EXAMPLE

6. SINIF MATEMATİK DERSİ GÜNLÜK DERS PLANI

BÖLÜM I

Dersin Adı	Matematik
Sınıf	6
Ünitenin Adı	Kesirlerin ondalık gösterimi
Konu	Ondalık kesirler arasındaki ilişkiler ve kesirlerin ondalık açılımları
Önerilen Süre	4 ders saati

BÖLÜM II

	HEDER 1: Ondalık kesirler arasındaki ilişkileri kavrayabilme **DAVRANIŞLAR** 1-Paydası 10 veya 10'un kuvveti şeklinde olan veya bu duruma getirilebilen kesirleri virgül kullanarak yazıp okuma 2-Sözle veya yazıyla verilen bir ondalık kesri virgül kullanarak yazıp okuma 3-Bir ondalık kesrin tam ve kesir kısımlarında bulunan basamakların adlarını söyleyip yazma 4-Bir ondalık kesrin tam ve kesir kısımlarında bulunan rakamların sayı ve basamak değerlerini söyleyip yazma 5-Bir ondalık kesrin farklı basamaklarında tekrar eden bir rakamın basamak değerleri arasındaki farklılığı söyleyip yazma 6-Bir ondalık kesri çözümleme 7-Çözümlenmiş olarak verilen bir ondalık kesri yazıp

Öğrenci Kazanımları / Hedef ve Davranışları	okuma 8-Bir ondalık kesre eşit olan diğer ondalık kesri yazma 9-İki ondalık kesri, büyüklük veya küçüklük sırasına koyup sembol kullanarak yazma 10-Verilen bir ondalık kesirden büyük veya küçük olan bir ondalık kesri yazma 11-En çok beş ondalık kesri, büyüklük veya küçüklük sırasına koyup sembol kullanarak yazma 12-En çok beş ondalık kesri sayı doğrusunda gösterme 13-Birinci ikinciye, ikinci üçüncüye göre aynı ilişki içinde bulunan üç ondalık kesirden, birinci ile üçüncü arasındaki ilişkiyi söyleme ve sembol olarak kullanarak yazma **HEDEF 2: Kesirlerin ondalık açılımını kavrayabilme** **DAVRANIŞLAR** 1-Paydası 10 veya 10'un kuvveti şeklinde yazılabilen kesirlerin ondalık açılımını yazma ve bunların sıfır devreden bir ondalık kesir olduğunu söyleme 2-Paydası 10 veya 10'un kuvveti şeklinde yazılamayan kesirlerin açılımının, devirli ondalık açılım olduğunu söyleyip yazma 3-Devreden sayısı sıfırdan farklı olan devirli ondalık açılımların, ondalık kesir olmadığını söyleme 4-Devirli ondalık açılımlardan devreden veya devretmeyen sayıları gösterip işaretleme 5-Her kesrin bir devirli ondalık açılımı olduğunu söyleyip yazma 6-Bir ondalık kesri, verilen bir basamağa göre yuvarlak yapma
Ünite Kavramları ve	Tanım kısmı, kesir kısmı, çözümleme, genişletme,

Sembolleri/ Davranış Örüntüsü	ondalık açılım, devreden, devirli ondalık açılım, yuvarlatma…
Öğretme-Öğrenme-Yöntem ve Teknikleri	Öğrencilerin konuyu çoklu zeka kuramına göre 8 etkinlik alanıyla kazanmaları sağlanacak
Kullanılan Eğitim Teknolojileri-Araç, Gereçler ve Kaynakça	Ders kitapları (MEB ONAYLI), çalışma kağıtları, tepegöz, şeker, boncuk, bozuk para… vb
Öğrenme-Öğretme Etkinlikleri	Sözel-Dilsel: Ondalık kesrin tanımı yapılır. Tam kısım ve kesir kısmı belirtilir. Basamak adları, ondalık kesirlerin karşılaştırılması öğrencilere ifade edilir.
	Sosyal-Kişiler Arası: 2,15<3,n6 karşılaştırılmasında n yerine yazılabilecek rakamlar kümesini yazmaları istenir.
	Mantıksal-Matematiksel: Ahmet0,3m, Naz 0,30m, Aslı0,300m ip almıştır. Hangisinin aldığı ip daha uzundur?
	İçsel-Bireysel: 0,75 ondalık kesrinden küçük ve büyük olan birer ondalık kesir yazmaları istenir.
	Görsel-Uzaysal: Ondalık kesirlerinin ondalık açılımları ve okunuşları bir tablo üzerinde gösterilir. Sayı doğrusu üzerinde Verilen noktalara karşılık gelen ondalık kesirleri yazmaları sağlanır.

BÖLÜM III

ONDALIK KESİRLER ARASINDAKİ İLİŞKİLER ve KESİRLERİN ONDALIK AÇILIMI

p/q biçimindeki rasyonel bir sayının payını paydasına böldüğümüzde sayının ondalık açılımını buluruz. Ondalık açılım ile bulunan sayılara ondalık sayılar denir.

ÖRNEK :

1. 13/5 = 2,6
2. 1/3=0,3333…

Bütün sayılar ondalık sayı olarak yazılabilir.

ÖRNEK : 6,0 = 6,00 = 6,000…

DEVİRLİ ONDALIK SAYILAR

Bazı ondalık sayılar sonsuza kadar devreder. Bunlara devirli ondalık sayılar denir. Ondalıklı sayı yoktur. Ondalıklı yazılış vardır. Çünkü onların hepsi rasyonel sayıdır.

ONDALIK SAYILARIN KESİR SAYISI OLARAK YAZILMASI

Devretmeyen ondalık sayıları kesre çevirirken sadece virgülden sonrasını kesre çevirip tam kısmı aynen yazmak daha kullanışlıdır.

Virgülden sonra kaç basamak var ise payda da 1'in yanına o kadar sıfır konulur.

ÖRNEKLER

1. 0,50 ondalıklı sayısını rasyonel sayıya çevirelim.
   0,50=50/100=1/2

2. 2,005 ondalıklı sayısını rasyonel sayıya çevirelim.
   2,005=2005/1000=401/200

DEVİRLİ ONDALIK SAYILARIN KESİR SAYISI OLARAK YAZILMASI

Yapılan işlemin ederi uzun ispatları gerektirmez Bu sebepten dolayı ispatsız formül verelim.

Ondalık sayısını kesirli olarak yazalım

1. Tam kısmı aynen yazarız
2. Ondalık kısımdan devretmeyen kısmı çıkararak kesrin payına yazarız.

3. Kesrin paydasına devreden kadar 9, devretmeyen kadar 0 koyarız.

Ölçme ve Değerlendirme

- ❖ Bireysel öğrenme etkinliklerine yönelik Ölçme-Değerlendirme
- ❖ Grupla öğrenme etkinliklerine yönelik Ölçme-Değerlendirme
  - Öğrenme güçlüğü olan öğrenciler ve ileri düzeyde öğrenme hızında olan öğrenciler için Ek Ölçme-Değerlendirme etkinlikleri

Alıştırmalar:

1. a) 2,65 b) 4,76 c) 0,77
   sayılarını küçükten büyüğe yada büyükten küçüğe sıralayınız.
2. $\frac{2}{5}$ sayısını ondalık kesre çeviriniz.
3. 2,5,8 sayılarını ondalık sayı olarak ifade ediniz.

Burada adı geçen "6.Sınıf Günlük Ders Planı"nı ayirac.com adresinden aldım. Ders planının "Bölüm III" teki "Ondalık Kesirler Arasındaki İlişkiler ve Kesirlerin Ondalık Açılımları" konularını M.S. Power Point kullanarak projeksiyon makinesi yardımıyla çeşitli gösterimlerden yararlanarak kesirli ifadeleri Powerpoint yardımıyla olabildiğince gösterebilmek öğrencilere anlatmanın daha faydalı olabileceğini düşünmekteyim.

Neden bunu seçtiğime gelecek olursak; 6. sınıf için kesirler, ondalık kesirler ve bunların ondalık açılımlarının öğrencilere soyut gelmesindense daha somut ve en azından daha görsel bir anlatımla, bu konunun daha iyi anlaşılabileceğini düşünmekteyim.

APPENDIX M: FINAL LESSON PLAN EXAMPLE

GÜNLÜK DERS PLANI

Sınıf Düzeyi: 5. sınıf

Ders: Matematik

Öğrenme Alanı: Geometri ve Ölçme

Alt Öğrenme Alanı: Üçgen ve Dörtgenler

Kazanımlar:

1. Çokgenleri isimlendirir, oluşturur ve temel elemanlarından kenar, iç açı, köşe ve köşegeni tanır.
2. Dikdörtgen, paralelkenar, eşkenar dörtgen ve yamuğun temel özelliklerini anlar.
3. Dikdörtgen, paralelkenar, eşkenar dörtgen ve yamuğun kareli veya noktalı kağıt üzerinde çizer; oluşturulanların hangi şekil olduğunu belirler.

Derste Verilen Kazanım: Dikdörtgen, dik üçgen ve karenin temel özelliklerini anlar.

Süre: 1 ders

Araç Gereçler: Renkli A4 kağıtları, akıllı tahta, tahta, telefon

Derse Giriş: Bugün 'geometrik cisim ne demektir?' bunu öğreneceğiz. Gördüğümüz her cismin aslında özel bir geometrik cisim olduğunun farkına varacağız ve bu geometrik cisimlerin özelliklerini öğreneceğiz.

Isındırma: Etrafımızda gördüğümüz geometrik cisimler nelerdir, örnekler veriniz. Bunların benzer ve farklı olduğu yönleri söyleyebilir misiniz?

Küp oluşturmak için origami etkinliği yapılır. Etkinliğin amacı, öğrencilerin kare, dikdörtgen, üçgen ve bu geometrik şekiller arasındaki ilişkileri öğrencilerin keşfetmesidir. Bu etkinlik süresince YouTube'dan origami ile küp yapımı videosu açılır. Video kullanarak hem her öğrencinin adımları takip etmesi hem de adımları doğru takip edemeyen veya tahmin edemeyen öğrencilerin de üç boyutlu görselle desteklenmeleri sağlanır. Bunun yanında video her adımda durdurularak öğrencilere sorular yönlendirilir ve geometrik cisimlerle ilgili eski bilgileri ortaya çıkarılır. Etkinliğin devamındaki adımlarda sorular öğrencilerin seviyesine göre sorulur. Videodaki adımlarda kullanılan matematiksel ifadeleri öğrencilerin de kullanması ve adımları doğru ifade etmeleri beklenir.

Öğretme Öğrenme Süreci: Sınıfa etkinlik uygulanması için renkli A4 kağıtları dağıtılır. Etkinliğin her aşamasında oluşan geometrik şekiller tek tek vurgulanarak anlatılır, geometrik şekillerin özelliklerinden bahsedilir ve bu süreçte soru cevap yöntemi ile diğer konularla ilişkilendirme yapılır. Öğrencilerden alınan cevaplara göre uygulamaya devam edilir veya her aşama tekrarlanır. Etkinlik sonlandığında öğrencilerden geometrik şekillerin özelliklerini bilmesi beklenir ve bir sonraki konu olan geometrik cisimlere altyapı hazırlanır.

ETKİNLİK PLANI

Elimizde bir kenarı uzun bir kenarı kısa ve kenarları birbirine dik olan bir kağıt var. Bu kağıt dikdörtgendir. Dikdörtgenimizin kısa kenarını taban alacak şekilde kağıdımızı çevirelim. Dikdörtgenimizin sağ üst köşesinden tutuyoruz ve köşemizi dik üçgen elde edecek şekilde uzun kenarımız ile birleştiriyoruz, dik üçgenin en uzun kenarı hipotenüstür ve hipotenüs kenarı üzerinde bir iz yapıyoruz. Kağıdımızın altında bir dikdörtgen oluştu. Oluşan bu dikdörtgeni elimiz yardımıyla oluşturduğumuz dik üçgenden ayırıyoruz. Kenarları birbirine eşit ve dik olan şekle kare denir. Kağıdımızın bütün kenarları eşit uzunluktadır ve dikdörtgende olduğu gibi bütün kenarları birbirine diktir bu durumda elimizde bir kare kağıt oluşmuştur ayrıca kağıdımızı açtığımızda üçgenimizin hipotenüsünün karemizin bir köşegeni olduğunu görüyoruz, karenin iki köşegeni vardır ve bunlar birbirine diktir.

1. Şekil: Oluşturduğumuz kare kağıdımız ve köşegeni.

Kare kağıdımızı kenarları üst üste gelecek şekilde ikiye katlıyoruz ve izimizi belli ediyoruz. Kağıdımızı açtığımızda iki tane eş dikdörtgen oluşturduğumuzu görüyoruz. İzimizi belli ettiğimiz yer, dikdörtgenlerimizin ortak uzun kenarı olmuştur. Şimdi dikdörtgenlerimizin ortak olamayan kenarlarını ortak olan kenarla üst üste gelecek şekilde katlıyoruz ve iki küçük eş dikdörtgen elde ediyoruz.

2. Şekil: Oluşturduğumuz iki küçük dikdörtgenimiz.

Şeklin bütününe baktığımızda bir dikdörtgen görüyoruz. Oluşturduğumuz küçük iki dikdörtgenden her biri, büyük dikdörtgenimizin $\frac{1}{2}$ ‘ sini (yarısını) temsil ediyor. Şimdi büyük dikdörtgenimizin kısa kenarları üst üste gelecek şekilde tam ortadan ikiye katlayalım ve bir iz oluşturalım. Bir kare elde etmiş olduk. Şekli tekrar açalım, iki eş kare elde etmiş olduk ve kerelerimizin bir kenarı ortaktır. Şimdi şeklimizi kenarlar o ortak kenarda birleşecek şekilde katlayalım ve bir kare elde edelim .

3. Şekil: En son olarak oluşturduğumuz kare.

En son katladığımız iki kenarı $90°$ açıyoruz, $90°$ dik açı demekti. Yani kenarlarımız tabanımıza dik olacak şekilde açıyoruz kenarlarımızı.

4. Şekil: En son elde ettiğimiz şeklimiz.

Bu yaptığımız şekilden aynı adımları izleyerek 6 adet şekil oluşturuyoruz.

5. Şekil: Yapmış olduğumuz 6 adet şekil.

En son oluşturduğumuz 6 şekilden iki tane alıyoruz ve birini dik kenarlardan herhangi birinin bize dönük olmasına dikkat ederek şeklimizi masa yerleştiriyoruz. Ardından ikinci şeklimizi $90°$ ile açtığımız tabanı üzerinde tutuyoruz ve masadaki şeklimizin ortasında bulunan soldaki dikdörtgeni üzerine yerleştiriyoruz.

6. Şekil: Çeşitli geometrik şekillerden oluşan şekil.

İki tane daha şeklimizden alıyoruz ve birini yine dik kenarı üzerinde masamıza yerleştirdiğimiz ilk şeklimizin içindeki sağ dikdörtgene yerleştiriyoruz. Aldığımız 4. parçamızı ise uzun kenarı ilk şeklimizin dik kanarını içine alacak şekilde ve dik kenarları içerde kalacak şekilde yerleştiriyoruz.

7. Şekil: Çeşitli geometrik şekillerden oluşan şekil.

Bir parça daha alıyoruz ve son yerleştirdiğimiz parçamızın karşısına aynı şekilde yerleştiriyoruz.

Şeklimize kutu görünümü vermek için yandaki kenarları dik konuma getirelim.

8. Şekil: Kutu görünümlü şekil.

Son parçamızı da şeklimizin açık kalan yüzünü kapatmak için kullanacağız. Üstte kalan iki dikdörtgenimiz ile son parçamızın iç kısmındaki dikdörtgenlerimiz birbiriyle $90°$’lik açı yapacak şekilde yerleştiriyoruz. Oluşan şekil bir geometrik cisimdir ve adı küptür.

Ölçme ve Değerlendirme: Socrative programı ile ders sonunda 10 soruluk bir değerlendirme yapılır.

socrative
by MasteryConnect

Name: ____________________ **Date:** __________

Quiz name: Geometri ve Ölçme

1. Yalnızca karenin 2 köşegeni vardır?
   - (A) True
   - (B) False

2. Bütün kenarları birbirine eşit ve dik olan şekle ne denir?
   - (A) Dikdörtgen
   - (B) Üçgen
   - (C) Kare
   - (D) Yamuk

3. Karenin en kısa kenarı hipotenüstür.
   - (A) True
   - (B) False

4. Sınıfınızda gördüğünüz geometrik şekillere 3 örnek veriniz.

   ____
   ____
   ____
   ____
   ____

5. Dikdörtgenden kare ve üçgen elde edemeyiz.
   - (A) True
   - (B) False

6. Dik üçgen, kare ve dikdörtgenin ortak özelliği varsa yazınız.

   ____
   ____
   ____
   ____
   ____

7. Küp nedir?
   - (A) Geometrik şekil
   - (B) Geometrik cisim
   - (C) Geometrik şekillerin genel adı
   - (D) Geometrik cisimlerin genel adı

8. Küp ve karenin benzerlikleri nelerdir?

9. Dik bir üçgen, bir karenin 1/2 sini (yarımını) temsil edebilir.

(A) True
(B) False

10. Yaptığımız etkinlikte kaç tane geometrik şekil kullandık?

(A) 4
(B) 3
(C) 2
(D) 1

APPENDIX N: TURKISH SUMMARY / TÜRKÇE ÖZET

Öğretim karmaşık yapılanmış bir süreçtir ve teknoloji entegrasyonu sürecin zorluklarına katkıda bulunur (Graham, Borup, & Smith, 2012). Bu nedenle, teknoloji ile öğretmek zor bir problemdir (Rittel & Webber, 1973). Eğitim, yüksek talepleri beraberinde getirmektedir ve son zamanlarda teknolojinin eğitimde yaygın olarak kullanılması için bir istek vardır (Kaufman, 2015). Öğrencilerin konuların temelini anlamasını kolaylaştırmak için dijital teknolojilerin kolaylıklarından faydalanarak ders planlarını yapılandırmada, eski müfredatı yeni yollarla öğretmede ve yeni müfredatlar geliştirmede teknoloji öğretmenlere daha fazla seçenek ve olanak sağladığından bu zorluğun etkin bir şekilde çözülmesi gerekmektedir (Koehler & Mishra, 2006). Bu çözüm öğretmenlerin öğretimde teknolojinin nasıl kullanılacağı konusunda gerekli bilgi ve deneyime sahip olmalarını gerektirir (Akbaba-Altun, 2006; Çakıroğlu & Haser, 2002). Ancak bazı öğretmenler, sınıf ortamında teknolojilerden faydalanmakta ve 21. yüzyıl matematik derslerinin gereksinimlerini tüm öğrenciler için karşılamada geride kalmaktadır (Kavanoz, Yüksel & Özcan, 2015; Zelkowski, 2011c). Birçok öğretmen dijital teknolojilere aşina değildir ve bu teknolojilere aşina olan öğrencilerle tanışırlar (Prensky, 2001). Sadece teknolojinin özelliklerini bilmek onları eğitimde kullanabilmek için yeterli değildir (Angeli & Valanides, 2009; Mishra, Koehler, & Kereluik, 2009). Öğretmenlerin, öğrencilerin kavramları anlamlı bir şekilde öğrenmelerinde yardımcı olacak dersler planlamak için teknolojilerin sunduğu olanaklardan nasıl yararlanabileceklerini bilmeleri gerekir (Lee & Hollebrands, 2008). Ayrıca, müfredattaki kazanım ve ilkelere uygun olan teknoloji entegre edilmiş derslerin tasarlanmasında ve uygulanmasında da deneyimli olmaları gerekmektedir (Lawless & Pellegrino, 2007).

21. yüzyıl eğitiminde, dünyadaki gelişimlere ayak uydurabilecek, teknolojiyi günlük hayatta kullanabilmek ve alan bilgisini geliştirebilmek için yeterli dijital becerilere sahip öğretmenler istenmektedir (Kaufman, 2015). Yakın

zamanda bildirilen eğitim standartları arasında, Uluslararası Eğitim Teknolojileri Derneği (ISTE, 2017) eğitimciler için çoğu dijital yeterlilikler hakkında olan standartlar yayınlamıştır. Bunlar arasında, liderlik özelliği altında, öğretmenlerin tüm öğrencilerin farklı ihtiyaçlarını karşılamak için eğitim teknolojisine, dijital içeriğe ve öğrenme fırsatlarına eşit erişimi sağlamayı amaçlaması beklendiği belirtilmektedir (ISTE, 2017). Öğretmenlerin alanlarındaki içerik ile uyumlu özgün öğrenme etkinlikleri tasarlamaları, aktif öğrenmeyi en üst düzeye çıkarmak için dijital araçları ve kaynakları kullanmaları ve öğrenmeyi destekleyen yenilikçi dijital öğrenme ortamları yaratmak için öğretim tasarım ilkelerini araştırıp uygulayabilmeleri beklenmektedir (ISTE, 2017).

Türkiye Milli Eğitim Bakanlığı (MEB), ortaokul (5, 6, 7 ve 8. sınıf) matematik müfredatında matematik derslerinde teknoloji kullanımını önermektedir (MEB, 2013). Müfredatta genel amaçlar arasında öğretmenlerin teknolojiyi öğrenme ve öğretme sürecinde etkin bir şekilde kullanmaları önerilmektedir. Bu hedefe ulaşmak için, öğretmenlerin teknoloji kullanabilmeleri için temel becerilere sahip olmaları ve teknoloji kullanarak matematik dersi içeriğini öğretmek için uygun pedagojik yöntemler kullanmaları gerekmektedir (MEB, 2013). Benzer şekilde, Amerika Birleşik Devletleri Ulusal Matematik Öğretmenleri Konseyi (NCTM) teknolojinin matematiğin etkili öğretim ve öğrenimi için gerekli olduğunu (NCTM, 2014) ve Matematik Öğretmeni Eğitimcileri Derneği (AMTE) farklı öğrenci ihtiyaçlarını tanımlamada ve karşılamada teknolojinin rolünü vurgulamaktadır. (AMTE, 2009).

Koehler ve Mishra (2006) Teknoloji, Alan ve Pedagoji olmak üzere üç temel bilgi arasındaki karmaşık etkileşimin oluşturduğu Teknolojik Pedagojik Alan Bilgisi'ni (TPAB), öğretmenlerin eğitimde teknoloji entegrasyonu ile ilgili bilgisine yönelik kavramsal bir çerçeve olarak sunmuşlardır. TPAB kavramsal çerçevesindeki bilgi yapıları ayrı ayrı incelenebildiği gibi uygulamada bu bilgi yapıları birbirine geçmiştir ve ayrıt edilemezler (Angeli & Valanides, 2005, 2009).

TPAB öğretimde teknolojiyi kullanmak için geliştirilmiş bütünleşik bir bilgidir (Koehler & Mishra, 2008; Mishra & Koehler, 2006) ve içerdiği bilgi yapılarının ötesine geçer (Angeli & Valanides, 2009, 2015; Koehler & Mishra, 2009). Thompson & Mishra, 2007; Yeh, Hsu, Wu, Hwang & Lin, 2014). Bu bakış açısıyla, TPACK ortam, öğrenci ihtiyaçları, pedagoji, teknoloji yeterlikleri, içerik (Angeli & Valanides, 2009) ve öğrencilerin öğrenmesini ve öğretmenlerin eğitimini geliştirmeyi kapsayan teknoloji entegrasyonu ile ilgili bilgi ve uygulama becerisi bütünüdür (Jen, Yeh, Hsu, Wu & Chen, 2016). Öğretmenler TPAB gelişimleri süresince teknoloji ile destekleyecekleri içerik ve buna uygun pedagojik yaklaşımlar arasında bağlantılar kurarlar.

TPAB kavramsal çerçevesi, yeni yaklaşımların ortaya çıkmasına elverişli olan geniş bir çerçevedir (Hewitt, 2008). Araştırmacılar, her biri TPAB kavramsal çerçevesinin içerdiği bir yapı üzerine kurulmuş olan, TPAB epistemolojisini benimseyen ve oradan türetilen çeşitli modeller önermiştir. Bunlardan biri olan TPAB-Pratik (TPAB-P) modelini (Yeh, Hsu, Wu, vd., 2014) diğer TPAB modellerinden ayıran yönler, TPAB-P'nin TPAB'ın bilgi ve uygulama tabanlı doğasından türetilmiş olması ve alana özgü TPAB gelişimini vurgulamasıdır. Buna ek olarak, TPAB-P değerlendirme, tasarım ve planlama ve uygulama olmak üzere üç pedagojik alana yönelik TPAB yeterliklerini dört seviyede tanımlayan iki boyutlu bir çerçevedir (Yeh, Lin, Hsu, Wu, & Hwang, 2015).

Öğretmenlerin derslerinde teknoloji kullanmaları üzerinde öğretmen eğitimi programlarında aldıkları eğitimin önemli bir etkisi olduğundan) öğretmen eğitimi programları süresince teknoloji entegre edilmiş etkinlikler planlamaları ve uygulamaları gerekir (Tondeur, Roblin, van Braak, Voogt, & Prestridge, 2017; Tondeur, Scherer, Siddiq, & Baran, 2017). Ancak, bu amacı öğretmen eğitim programlarında yerine getirmek zor ve tartışmalı bir konu olmuştur (Niess, 2011). Bu nedenle, öğretmen eğitim programlarındaki ders içeriklerinin iyileştirilmesi yönünde bir reform yapılması gerekmektedir (Koehler, Mishra & Yahya, 2007; Niess, 2006). Bu iyileştirmede amaç öğretmen adaylarının alana özgü ve pedagoji ile ilişkilendirilmiş (Tondeur, Roblin vd., 2017) ve müfredat hedefleriyle harmanlanmış teknoloji entegrasyonu deneyimleri yaşamalarını sağlamaktır (Agyei & Voogt, 2011a). Öğretmen eğitim programlarının içeriğinin yenilenmesinde TPAB çerçevesinin kullanılması, öğretmen adaylarının eğitimde etkili teknoloji kullanımı konusunda yetkin olarak yetişmesi (Koehler & Mishra, 2009) ve eğitime teknoloji entegrasyonu ile ilgili deneyim kazanabilmelerini destekleyen verimli ortamların tasarlanması için önerilmektedir (Agyei & Voogt, 2012).

Araştırmanın Amacı ve Araştırma Soruları

Bu çalışmanın amacı ortaokul matematik öğretmen adaylarının (OMÖA) TPAB-P gelişimlerini desteklemek ve incelemektir. Bu amaç doğrultusunda TPAB-P modeli temel alınarak Matematik Eğitiminde Teknoloji Kullanımı (METK) dersi planlanmış ve uygulanmıştır. Araştırmada aşağıdaki araştırma sorusuna ve ona ait alt sorulara yanıt aranmıştır.

1. Matematik Eğitiminde Teknoloji Kullanımı dersi ortaokul matematik öğretmen adaylarının TPAB-P gelişimlerini nasıl etkilemektedir?
    a) Ortaokul matematik öğretmen adaylarının Matematik Eğitiminde Teknoloji Kullanımı dersinin başında TPAB-P yeterlik düzeyi nedir?
    b) Ortaokul matematik öğretmen adaylarının Matematik Eğitiminde Teknoloji Kullanımı dersinin sonunda TPAB-P yeterlik düzeyi nedir?

Kavramsal Çerçeve

TPAB-P (Yeh, Hsu, Wu vd., 2014) öğretmenlerin öğretim uygulamaları için ve bu uygulamaları yaparak geliştirdikleri teknoloji kullanımı bilgisidir (Yeh, Lin, Hsu, vd., 2015). Diğer TPAB modellerden farklı olarak, TPAB-P hem bilgiye hem de deneyime dayanmaktadır (Yeh, Hsu, Wu vd., 2014). Öğretmenlerin eğitimde teknoloji kullanma bilgisini geliştirmek ve değerlendirmek için TPAB-P modeli dört düzeyde ve üç pedagojik boyutta TPAB-P yeterliğinin belirlendiği çok boyutlu bir çerçeve önermektedir (Jen vd., 2016). TPAB-P modeli yardımıyla öğretmenler teknoloji entegre edilmiş dersler planlamada ve uygulamada başarılı olabilirler (Yeh, Hsu, Wu vd., 2014). TPAB-P modelindeki dört yeterlik seviyesi ve seviyelere ait olan kriterler ve göstergeler (Yeh, Lin, Hsu vd., 2015) son halini Jen vd. (2016) tarafından yapılan çalışmada almıştır.

Alanyazın İncelenmesi

TPAB alanyazınında, neyin eksik olduğunu tanımlamak, öğretmen yetiştirme programlarında öğretmen adaylarının TPAB gelişiminin nasıl olduğunun bilinmesi için oldukça önemlidir. TPAB, öğretmenin teknoloji ile etkin öğretme hakkındaki bilgisidir (Mishra & Koehler, 2008). Bütünleştirici görüşe göre, TPAB yedi bilgi türünden ve bunların entegrasyonundan oluşmaktadır (Angeli vd., 2016). Öğretmen adaylarının TPAB'ını araştırmak amacıyla TPAB bileşenlerinin gelişimlerini ayrı ayrı araştıran çalışmalar vardır (bkz. Cox & Graham, 2009; Graham, Borup & Smith, 2012; Jaipal & Figg, 2015). Diğer taraftan, dönüşümcü bakış açısıyla TPAB, içerdiği bilgi yapılarının ötesine geçen bütünleşik ve bileşenlerinden farklı bir bilgi bütünüdür (Angeli & Valanides, 2009, 2015; Koehler & Mishra, 2009; Thompson & Mishra, 2007; Yeh, Hsu, Wu vd., 2014). Bu bakış açısıyla, TPACK bağlam, öğrenci ihtiyaçları, pedagoji, teknoloji yeterlikleri ve içerik bilgisini (bkz. Angeli & Valanides, 2009) ve öğretmen adaylarının öğrencilerin öğrenmesini ve öğretmenlerin öğretimini geliştirmek amacıyla teknolojiden faydalandığı bilgi ve uygulamaları içermektedir (Jen vd., 2016).

TPAB, teknoloji bilgisinden daha fazlasını içerir. TPAB'da yeterli olmak için, öğretmenlerin belirli bir içeriğin öğrenilmesini desteklemek için uygun pedagojik yöntemlerle etkili teknolojileri seçmeleri, öğretimi öğrenme ortamına uygun olarak tasarlamaları ve bu planı tasarlandığı şekilde uygulamaları gerekmektedir. Bu nedenle TPAB, alan temelli çalışmaların odağı haline gelmelidir. TPAB'ın alana özgü olarak incelenmesine ihtiyaç vardır (Baran & Canbazoğlu-Bilici, 2015; Chai vd., 2013, Voogt vd., 2013). Grafik hesap makineleri (Chai vd., 2013; Ozgun-Koca vd., 2010, 2011), dinamik geometri yazılımları (Chai vd., 2013) ve sanal manipülatifler (Ozgun-Koca & Meagher, 2012) hem öğrencinin öğrenmesini hem de öğretmenin öğretimini geliştirmektedir. Buna ek olarak, bu teknolojilerin matematik öğretiminde kullanılması temsiller arasında dinamik ilişkiler kurulmasını sağlar (Ozgun-Koca vd., 2010).

TPAB, öğretmen adaylarının teknolojinin kullanımı ile ilgili deneyim kazanmaları için fırsat yaratan ortamların tasarlanması için etkin bir çerçevedir (Agyei & Voogt, 2012; Tondeur, van Braak vd., 2012). Koehler ve Mishra (2009), pedagoji, alan bilgisi ve teknolojik bilgi ve becerileri bütünleştirebilen ve teknolojiyi eğitimde etkin bir biçimde kullanabilen öğretmen adayları yetiştirmek için öğretmen eğitimi programlarının dönüşümünde TPAB çerçevesinin kullanılmasını önermiştir. Alanyazında bu konuda birçok yaklaşım bulunmaktadır. Yeh, Hsu, Wu vd. (2014) bu yaklaşımlardan biri olan TPAB-P çerçevesini bilgi tabanlı ve deneyim odaklı öğretmen yeterliklerini içeren bir çerçeve olarak sunmuştur. Eğitimde teknolojinin uygulamalı kullanımını temel alan TPAB-P çerçevesinde, Değerlendirme, Planlama ve Tasarım ile Uygulama alanlarındaki dört yeterlik seviyesi ortaya konmuştur (Jen vd., 2016). TPAB'ın hem bilgi hem de uygulamaya dayalı doğasından türeyen ve alana özgü gelişimi vurgulayan TPAB-P çerçevesi bu yönleriyle diğer TPAB modellerinden farklılık gösterir.

TPAB çerçevesi ve ona bağlı olarak geliştirilen diğer modeller, teknoloji entegrasyonu ile ilgili yetkinlikleri geliştirmeyi amaçlayan derslerin tasarlanması için kullanılmıştır. Alanyazındaki çalışmalarda, öğretmen adaylarının teknolojiyi öğretime profesyonel olarak dahil edebilmeleri için öğretmen eğitimi derslerinde teknolojilerin matematik eğitimine katkılarını araştırabilecekleri ortamlar oluşturulmuştur. Bu dersler, öğretmen adaylarının eğitimde teknoloji kullanımına yönelik gelişimlerini olumlu yönde etkilemiştir (Angeli & Valanides, 2009; Chai vd., 2010). Öğretmen adaylarının TPAB gelişimini ders kapsamında desteklemeyi amaçlayan araştırmalarda yöntem dersini yeniden tasarlayan (Haciomeroğlu vd., 2010; Lee & Hollebrands, 2008; Meng & Sam, 2013; Ozgun-Koca vd., 2010), öğretim dersleri (Agyei & Voogy, 2012; Balgalmis, 2013) ve matematik dersleri (Durdu & Dag, 2017; Kurt, 2016; Meagher vd., 2011) kapsamında çalışan, bu derslerin birkaçında eşzamanlı olarak (Mudzimiri, 2012; Niess, 2005) ya da yeni dersler tasarlayarak (Akkaya, 2016; Akyüz, 2016; Bowers & Stephens, 2011; Cavin, 2008) yapılmış çalışmalar bulunmaktadır. Bu çalışma ise ilgili alan yazında önerildiği gibi etkili stratejiler kullanılarak tasarlanan ve uygulanan Matematik Eğitiminde Teknoloji Kullanımı (METK) dersi kapsamında gerçekleştirilmiştir. METK dersi, bu etkili stratejilerin bir kısmını ansıtan ilkeler doğrultusunda oluşturulmuştur. Tondeur, van Braak vd. (2012), öğretmen adaylarının teknolojiyi öğretim uygulamalarında etkili kullanımlarının geliştirilmesini amaçlayan öğretmen eğitim programlarındaki etkili uygulamaların özellikleri arasında teorinin pratiğe aktarımı, tasarım yoluyla öğrenme, öğretmen eğitimcinin rol model olması ve işbirlikli öğrenme gibi ana temaları vurgulamıştır. Bunlara ek olarak, sürekli geri bildirim de eğitimde teknolojinin etkin kullanımı becerilerinin geliştirilmesi açısından destekleyici ve etkilidir (Niess, 2005; Tondeur, van Braak vd., 2012).

Bu çalışma, alanyazında vurgulanan özelliklerin tek bir bağlamda toplanması bakımından özgündür. OMÖA'nın TPAB-P gelişimlerinin TPAB-P ilkelerine dayalı olarak tasarlanmış ve teknoloji ile güçlendirilmiş bir ders kapsamında desteklenmesi ve incelenmesi amaçlanmıştır. OMÖA'nın TPAB-P gelişimi, hem kendi gelişimleri ilgili algıları hem de araştırmacının gözlemine dayalı gelişimleri ile ilgili bilgi almayı sağlayan veri kaynakları aracılığıyla araştırılmıştır.

Yöntem

OMÖA'nın TPAB-P gelişimilerini desteklemek ve incelemek amacıyla veri toplanması ve analiz edilmesinde nitel araştırma stratejileri kullanılmıştır. Bu çalışma, bütüncül bir tasarıma sahip olan tek durum çalışması türünde tasarlanmıştır. Bu çalışmadaki durumu, METK dersini alan İlköğretim Matematik Öğretmenliği lisans programına kayıtlı 11 dördüncü sınıf öğrencisi oluşturmaktadır. Programda dördüncü sınıfta olan 17 öğrenciden 2015-2016 öğretim yılında beş krediye sahip seçmeli ders olan METK dersine kayıt yaptıran 11 öğrenci bu çalışmanın katılımcılarını oluşmuştur. Yaşları 21 ile 27 arasında değişen 11 öğrenciden 10'u kız ve biri erkek öğrencidir.

Çalışmada, METK dersini veren araştırmacı, katılımcı-gözlemci rolünü üstlenmiştir. Katılımcı-gözlemci rolü, araştırmacının araştırmanın gidişatını kontrol etmesini, dersi organize etmesini ve katılımcıları hem öğretmen hem de araştırmacı bakış açısından gözlemlemesini sağlamıştır.

Matematik Eğitiminde Teknoloji Kullanımı Dersi İçeriği

METK dersinin genel amacı, teknolojiyi matematik eğitiminde etkili şekilde kullanabilen geleceğin öğretmenlerini hazırlamaktır. METK dersi Eğitim Fakültesi'ndeki matematik laboratuvarında yürütülmüştür (bkz. Ek B). Bazı dersler ise her katılımcının bir bilgisayar kullanabileceği bilgisayar laboratuarında yapılmıştır. METK dersi, Yeh, Hsu, Wu vd. (2014) tarafından önerilen TPAB-P çerçevesi temel alınarak planlanmış ve tasarlanmıştır.

METK dersi, TPAB (Koehler & Mishra, 2008, 2009) ve TPAB-P (Yeh, Hsu, Wu, vd., 2014; Yeh, Chien, Wu vd., 2015) modellerinin ilkelerine dayalı olarak tasarlanmış, planlanmış ve uygulanmıştır. Bu ilkeler dönüşümcü yaklaşım, işbirlikli öğrenme, etkinlik destekli öğrenme ve uygulamaya dayalı öğrenmedir. Bu ilkelerin METK dersinde tanımlanması ve uygulama şekilleri aşağıda açıklanmıştır.

Dönüşümcü yaklaşım: TPAB, dönüşümcü bakış açısına göre, bileşenlerinin ötesine uzanan bilgiler bütünüdür (Angeli ve Valanides, 2005, 2009). Bu açıdan METK dersi, TPAB-P bileşenlerinin entegrasyonu üzerine kurulmuştur. METK dersindeki bu bileşenler matematik eğitiminde teknolojinin rolünün incelenmesi, eğitim teknolojileri ve teknoloji entegrasyonuna uygun öğretme ve öğrenme yöntemlerinin araştırılması, eğitim teknolojileri kullanılarak matematik derslerinin yeniden tasarlanmasıdır. Bu konular dönüşümcü yaklaşım ile ele alınmıştır.

İşbirlikli öğrenme: Teknoloji entegre edilmiş öğretim materyallerinin tasarlanmasında işbirlikli çalışma TPAB gelişimini artırmaktadır (Koehler & Mishra, 2005; Koehler vd., 2007; Polly vd., 2010; Tondeur, van Braak vd., 2012). Dahası, işbirlikli çalışma pratik kullanımlı yüksek kaliteli materyaller ortaya çıkarmayı sağlar (Yeh, Hwang, & Hsu, 2015). Bu nedenle, METK dersinde öğretme ve öğrenme süreci işbirlikli öğrenme yaklaşımına dayalı tasarlanmıştır. İşbirliği ortamı katılımcıların fikir, deneyim ve beceri alışverişinde bulunmalarını sağlamıştır. Ayrıca, katılımcıların her bir etkinlikte teknoloji destekli materyaller tasarlarken birbirleriyle etkileşime girmesi ve birbirlerinden öğrenmeleri önemli kazanımlar olarak kabul edilmiştir. Dersin ikinci bölümünde her etkinlikte teknoloji destekli tasarım önerileri üzerinde çalışırken gruplar içinde yapılan tartışmalar, katılımcıları grup içindeki farklı görüşlerden ortak bir görüş oluşturmaya yönlendirmiştir. Grup içi tartışmalarının ardından, büyük grup tartışmalarında farklı görüşlerin ortaya çıkarılması fırsatını sağlamıştır.

Etkinlik destekli öğrenme: Etkinlik destekli öğrenme, müfredattaki kazanımlara uygun etkili teknoloji destekli öğretim planlamasının öğrenilmesine yardımcı olur (Harris & Hofer, 2009) ve TPAB-P gelişimini destekler (Yeh, Chien, Wu, vd., 2015). Bunun yanı sıra, etkinlik destekli öğrenme, odağı öğretmen merkezli yaklaşımdan öğrenci merkezli öğretime kaydırmaktadır (Agyei & Voogt, 2012). Katılımcılar bu araştırmadaki her bir etkinlikte verilen konu hakkında araştırma yapmış; teknolojiler, katkıları ve örnek kullanımları hakkında bilgi toplamışlardır. Son olarak da, katılımcılar matematik müfredatındaki öğrenme hedeflerini ve matematiksel konular hakkındaki kavram yanılgılarını araştırmış ve bu bilgileri teknoloji destekli bir öğrenme ürünü oluşturmak için analiz etmiş ve sentezlemişlerdir.

Uygulama temelli öğrenme: TPAB-P, eğitimcilerin uygulamalarını teknolojiyle bütünleştirerek kullanabilecekleri bir bilgi bütünüdür ve yalnızca teknolojinin pratikte kullanılmasıyla geliştirilebilir (Jen vd., 2016). TPAB gelişimi için pedagojik yöntem, teknolojik araçlar ve alan bilgisine ihtiyaç duyulmasına rağmen, temel odak farklı öğretim amaçlarına hizmet etme amacıyla teknolojinin öğrenilmesi ve uygulamada kullanımı üzerinde olmalıdır (Jen vd., 2016). Buna göre, METK dersinin uygulamaya dayalı içeriği, katılımcıların teknolojilerle etkileşim yoluyla TPAB-P'lerini geliştirmeyi ve güçlendirmeyi, destekleyici bir ortamda teknoloji ile güçlendirilmiş faaliyetler gerçekleştirmeyi ve Jen vd. (2016) tarafından önerilen teknoloji entegre edilmiş tasarımlar oluşturmayı ve uygulamayı amaçlamaktadır. Böylece, METK dersinde tüm etkinliklerin, tartışmaların ve ödevlerin temelinde uygulama vardır. Hem dersteki etkinlikler hem de mikro öğretim ödevi katılımcılara teorik bilgilerini pratiğe dönüştürmek için fırsatlar sunan öğretim deneyimleri olmuştur.

Yukarıda detaylı olarak açıklanan dört ilke temel alınarak tasarlanan METK dersi başlıca üç bölümden oluşmaktadır: 1) TPAB modelinin teorik altyapısı, 2) Eğitim teknolojileri: Araştırılma, tasarlama ve yansıtma ve 3) Teknolojinin matematik eğitimine entegrasyonu. Ders haftada 3 saat ve toplamda 42 ders olarak 14 haftadan oluşan bir dönem boyunca sürdürülmüştür.

Veri Toplama Araçları ve Veri Analizi

Veri seti, METK dersi öncesinde, ders esnasında ve ders sonrasında çeşitli veri kaynaklarından toplanmıştır. Bu çalışma için kanıt sağlayan veri kaynakları dokümantasyon, gözlem ve görüşmedir. METK dersine başlamadan önce, katılımcılara iki anket uygulanmış ve teknoloji bilgileri ve teknolojiyi ders tasarımında kullanma becerilerini belirlemek üzere bir ders planı hazırlama görevi verilmiştir. Katılımcılar METK dersi boyunca 14 hafta gözlemlenmiştir. Gözlem video kayıtları, METK dersinin bir dönem boyunca işlenişi ve ders boyunca katılımcıların sergiledikleri performanslardan oluşmaktadır. Araştırmacı ders sırasında ve dersten hemen sonra saha notları kaydetmiştir. Katılımcılara, etkinliklerin tamamlandığı 12. haftaya kadar ikinci bir ders planı hazırlama görevi verilmiştir. Her katılımcı, mikro öğretim yöntemiyle ders planını diğer katılımcılara sunmuştur. On bir mikro öğretim seansı video ile kayıt edilmiştir. Her bir mikro öğretim tamamlandığında, katılımcılar akran değerlendirme formunu doldurarak diğer katılımcıların mikro öğretimini (bkz. Ek F) ve her katılımcı öz değerlendirme formunu doldurarak kendi mikro öğretimini değerlendirmiştir (bkz. Ek G). METK dersi sona erdikten sonra, katılımcıların teknolojiyi matematik eğitimine entegre etme konusundaki genel görüşlerini belirlemek için yarı yapılandırılmış bireysel görüşmeler yapılmıştır.

Veri analizinde içerik analizi tekniği kullanılmıştır. Nitel çalışmalarda kanıtları en üst düzeye çıkarmak için veri kaynaklarının çeşitlendirilmesi gerekir (Yin, 2003). Kapsamlı değerlendirme rubriği katılımcıların TPAB-P düzeyini belirlemek için toplanan tüm veriyi değerlendirmek için kullanılmıştır. Rubrik, Değerlendirme, Planlama ve Tasarım ve Uygulama pedagojik alanları dahilinde her bir TPAB-P seviyesine ait bilgi ve beklenen davranışlar ile ilgili kriterlerden oluşmaktadır.

Bulgular

Öncelikle katılımcıların başlangıçtaki TPAB-P seviyeleri belirlenmiştir. Daha sonra katılımcıların bireysel TPAB-P gelişimleri üç alanda sınıflandırılan TPAB-P modeli doğrultusunda önerilen seviyelere göre belirlenmiştir. Benzer yeterlilik seviyelerinde belirlenen katılımcılar bu seviyelere göre gruplandırılmıştır. Son olarak, her gruptaki katılımcıların uygulamaları ve görüşleri ayrıntılı olarak betimlenmiştir.

METK Dersinin Başlangıcında OMÖA'nın TPAB-P Seviyeleri

Katılımcıların ders öncesi TPAB-P seviyeleri, Değerlendirme alanı ve Planlama ve Tasarım alanı olmak üzere iki alan için belirlenmiştir. Ders öncesi TPAB-P seviyelerinin belirlenmesi için katılımcıların iki ankete verdikleri yanıtlar ve teknoloji entegre ettikleri ders planları analiz edilmiştir.

Öğretmenlik Mesleğine Yönelik Görüşler Anketi'nde bulunan sorulara katılımcıların verdiği cevaplar arasında teknolojik bilgiye dair bulgu bulunamamıştır. Katılımcıların, teknolojik bilgiyi bir öğretmenin sahip olması gereken pedagojik bilgi ve alan bilgisi gibi bir bilgi türü olarak görmedikleri tespit edilmiştir. Teknoloji yalnızca P9 ve P11 tarafından, kullanıldığı ortamı ve buna yönelik bir ihtiyacı ifade etmeden diğer eğitim materyalleri arasında bir araç olarak belirtilmiştir.

Teknoloji Kullanımı Anketi için verilen cevaplar, katılımcıların daha önce bildiği ve kullandığı 18 tür teknoloji olduğunu ortaya çıkarmıştır. Eğitimde teknoloji kullanımı ile ilgili olarak sunum hazırlama, poster, bulmaca, kavram haritaları ve testler hazırlama, grafikler ve geometrik şekiller çizme, koordinat sistemini keşfetme ve hesaplama yapma gibi cevaplar anketten elde edilen amaçlar arasında yer almaktadır. Sonuçlar, her katılımcının bu teknolojilerden en az ikisi hakkında bilgisi olduğunu göstermiştir. Birçok teknolojinin farkında olmalarına ve daha önceden eğitim amaçlı kullanmış olmalarına rağmen katılımcıların bu teknolojileri ders planlarında kullanmadıkları tespit edilmiştir.

Katılımcıların ders planlarında Powerpoint, projeksiyon, GeoGebra ve video olmak üzere dört tür teknoloji kullandıkları tespit edilmiştir. P2 ve P9'un ders planlarında herhangi bir teknoloji entegrasyonu yapamadığı; P7, P8 ve P10'un ise ders planı hazırlamadığı tespit edilmiştir. Ders planlarında teknolojinin kullanımını öneren altı katılımcı teknolojiyi nasıl kullanacaklarının ayrıntılarını ifade edememiştir. Ders planlarında ortaya çıkan amaçlar, kavramların somutlaştırmak ve görselleştirmek, öğrencileri motive etmek ve konuyu özetlemektir. Ancak katılımcılar, teknoloji entegrasyonunun içeriğini, nasıl entegre edileceğini ve uygulanacağını belirtmemişlerdir. P1 ve P4 matematiksel içeriğin görsel olarak gösterilmesi için Powerpoint ve projeksiyon kullanımı önermiştir. Ayrıca, P6

Powerpoint kullanımını önermiş, ancak bu kullanımı ders kapsamında nasıl planladığını belirtmememiştir. Bir başka planda, üçgen benzerliğinin gösterilmesi ve paralelkenarın alanının görsel temsili için GeoGebra önerilmiştir. Öğrencileri motive etmek ve konu özetlemek için ise video kullanılması önerilmiştir. P3 ise üçgenlerin iki özelliğinin müzikli bir şekilde söylendiği bir video kullanılmasını önermiştir. Teknolojinin kullanım amaçları, teknoloji kullanımlarının öğretimi destekleyici olduğu ancak geliştirmediği göstermiştir. Teknoloji entegrasyonu önerilerinin, teknolojilerin faydalarının kullanılmadığı ve ders hedeflerini karşılamada yetersiz kalan amaçları olduğu belirlenmiştir. Bunun yanı sora, kullanılan teknolojiler ders planlarındaki matematiksel içerikle uyumsuzdur. Ayrıca, seçilen teknolojilerle eşleştirilmiş pedagojik yöntemler belirtilmemiştir.

Teknoloji, ders planlarında sadece dersin sınırlı bir bölümünde kullanılmak üzere planlanmış, öğrencilere teknoloji kullanımı ile ilgili altyapı oluşturmaları için örnek gösterilmemiştir. Bu doğrultuda, teknolojik içerik barındıran altı ders planından beşinde teknolojik içerik, teknolojinin öğretmen merkezli olarak kullanılmasını hedeflemiştir. P1 tarafından hazırlanan ders planında ise GeoGebra'nın öğrenci merkezli bir ortamda kullanılması önerilmiştir. P1, Powerpoint'in ve GeoGebra'nın öğrenci merkezli bir ortamda kullanılmasını önererek daha iyi bir teknolojik entegre edilmiş ders planı tasarlamıştır. Bu öneriler göz önünde bulundurulduğunda daha yüksek düzeyde bir TPAB-P düzeyinde belirlenmesi beklenilebilir. Ancak ders planında bu teknolojilerin kullanım amacı, uygulanması gereken adımlar ve yönergeler, teknoloji destekli etkinliklerin içerik ve detayları, öğretmenin rolü ve öğrencilerden beklentiler gibi öğretimsel detayların olmadığı görülmüştür. Bunlara ek olarak, konunun bir bilgisayar laboratuarında öğrencilerin bireysel performansları doğrultusunda GeoGebra üzerinde öğretilmesini planlayan P1, ders planındaki soruları GeoGebra'da çözmek daha uygun olmasına rağmen, soru çözümlerinde üçgenlerin çizimi için cetvel kullanılması tavsiyesinde bulunmuştur. Ayrıca, GeoGebra'nın dinamik ortam ve çoklu gösterim fonksiyonları yerine sadece çizim ve ölçüm fonksiyonlarına ağırlık vermiştir.

Teknoloji Kullanım Anketi'ne verilen yanıtlara göre, tüm katılımcıların çeşitli teknolojilerden haberdar oldukları ve bazı derslerde eğitim amaçlı kullandıkları ortaya çıkmıştır. Ancak, anketlere verilen cevaplarda teknolojiyi öğretmen yetkinliği olarak belirtmedikleri görülmüştür. Sadece P9 ve P11, söz konusu teknolojilerin bir araç olduğunu ifade etmiştir. Katılımcılar daha önceden çeşitli teknolojileri tanıyıp kullanmış olsalar da, başlangıç ders planlarındaki teknoloji tercihlerinin yetersiz olduğu tespit edilmiştir. Katılımcıların ders planlarında kullandıkları teknolojiler ders tasarımlarına mevcut öğretimden daha fazla katkıda bulunmadığı gibi teknolojinin olanaklarından çok sınırlı ölçüde faydalanabildikleri görülmüştür. Bu bulgulara göre, tüm katılımcıların TPAB-P düzeyinin Planlama ve Tasarım alanında 1. seviyede olduğu belirlenmiştir. Buna ek olarak, katılımcılardan hiçbiri anket ve ders planında teknolojinin ölçme ve değerlendirme amaçlı kullanımından bahsetmemiştir. Bu nedenle, tüm katılımcıların TPAB-P düzeyinin Değerlendirme alanında 1. seviyede olduğu belirlenmiştir.

METK Dersi Sonunda OMÖA'nın TPAB-P Seviyeleri

Katılımcıların TPAB-P düzeyleri ikinci ders planlarına, ders planlarındaki dersi anlattıkları mikro öğretim videolarına, mikro öğretim videolarına yönelik akranları ve kendileri tarafından doldurulan akran ve öz değerlendirme formlarına ve METK dersinin sonunda yapılan bireysel görüşmelere göre belirlenmiştir. Her katılımcı için TPAB-P rubriği bu kaynaklardan elde edilen veriler kullanılarak ayrı ayrı doldurulmuştur. Rubrik, TPAB-P ile ilgili göstergeler ve öğretmenlerin örnek davranışlarından oluşmaktadır. Jen vd. (2016) tarafından oluşturulmuş TPAB-P göstergeleri Yeh et al. (2015) tarafından hazırlanmış olan TPAB-P yeterlilik seviyelerini açıklamaktadır. Jen vd. (2016) her bir göstergenin anlamını açıklığa kavuşturmak için örnek öğretmen görüşlerini ve davranışlarını belirtmişlerdir. Bu çalışmada, bu göstergeler yeniden yapılandırılmış ve bir değerlendirme formuna dönüştürülmüştür. Analizler sonucunda her bir katılımcının nihai TPAB-P seviyesi belirlenmiştir.

Katılımcıların TPACK-P seviyeleri üç alanda farklılık gösterebilmektedir. Örneğin, P2, P5 ve P6 Değerlendirme alanında 4. seviyede, Planlama ve Tasarım ile Uygulama alanlarında 3. seviyede olarak belirlenmişlerdir. Her alanda aynı performansa sahip olan katılımcılar da bulunmaktadır. Örneğin P11'in, üç alanda da 4. seviyede olduğu tespit edilmiştir. Ayrıca, 1. seviyede kalan bir katılımcı bulunmamaktadır.

OMÖA'nın TPAB-P Gelişimlerinin Gruplar Halinde İncelenmesi

Sonuçlar TPAB-P modeli temelli hazırlanmış ve uygulanmış METK dersinin OMÖA'nın eğitimde teknoloji entegrasyonu yeterliliklerini güçlendirdiğini göstermiştir. OMÖA'nın başlangıçta TPAB-P düzeyleri, Kullanım Eksikliği Seviyesi olan 1. seviyede tespit edilmiştir. OMÖA'nın METK dersinin sonunda TPAB-P seviyelerinin arttığı ortaya çıkmıştır. Bu nedenle, TPAB-P seviyelerinin, her üç pedagojik alanda da seviye 1'den daha yüksek seviyelere yükseldiği tespit edilmiştir. Katılımcılar ders sonrası TPAB-P düzeylerinin sonuçlarına göre gruplandırılmıştır. Katılımcılar, Çoğunlukla Basit Benimseme grubu, Çoğunlukla Kaynaştırıcı Uygulama grubu ve Çoğunlukla Yansıtıcı Uygulama grubu olan ve sırasıyla 2, 3 ve 4 seviyelerine karşılık gelen üç gruba yerleştirilmiştir.

Grup 1: Çoğunlukla Basit Benimseme

Çoğunlukla Basit Benimseme grubuna dahil olan katılımcılar P4, P7 ve P10'dur. Çoğunlukla Basit Benimseme grubundaki katılımcılar, teknolojiyi derse katılımı arttırmak için motive edici bir platformda tekrara dayalı uygulamalar kullanarak matematik öğrenimini değerlendirme amacıyla kullanma eğilimi göstermişlerdir. Temel olarak çevrimiçi değerlendirme platformu olan Kahoot uygulamasını ses ve yazı tipi (P4), Socrative uygulamasının görünümü (P10) ve hem öğrenciler hem de öğretmenler için kullanıcı dostu olması (P4, P7 ve P10) gibi fiziksel özellikleri için tercih etmişlerdir. Katılımcıların tamamı kapsamlı sorular hazırlamış ve programların sunduğu farklı soru tiplerini kullanabilmişlerdir. Katılımcıların çevrimiçi değerlendirme uygulamalarında soruların çözümleri için ayırdığı zamanın yetersiz olduğu belirlenmiştir (P4, P10).

Katılımcılar özellikle ders planlarında ve görüşmelerde matematiksel içeriği dijital olarak sunma amaçlarının öğrenci motivasyonunu matematik öğrenmeye karşı artırmak olduğunu vurgulamışlardır. P4, Microsoft Word'de üslü sayılar konusuyla ilgili örnek soruları özetleyip sunmak için çalışma sayfaları hazırlamış; P7, tahmin stratejileri konusunu öğretmek için hesap makinesi kullanmayı planlanmış; ve P10, öğrencilerin dikkatini çekmek ve öğretimi kolaylaştırmak için uzunluk ölçümlerinde GeoGebra kullanılmasını önermiştir. Ayrıca, P4, P7 ve P10 ve diğer katılımcılar, değerlendirmelerinde bu grupta bulunan katılımcıların öğretimlerinde görselliğin eksik olduğunu belirtmişlerdir. Poster hazırlama (P7, P10) ve GeoGebra programını kullanma (P10) bu ihtiyacı gidermek için verilmiş olan öneriler arasındadır. Ayrıca bu gruptaki katılımcılar, öğretimi geliştirmek ve öğrenci öğrenimini teşvik etmek için teknolojiden yararlanma konusunda olumlu görüşlere sahip olduklarını göstermişlerdir. Bu gruptaki katılımcıların öğretime teknolojinin entegrasyonu ile ilgili görüşlerinin, ders planları ve mikro öğretim uygulamalarıyla benzer olarak öğretmen merkezli olduğu tespit edilmiştir.

Grup 2: Çoğunlukla Kaynaştırıcı Uygulama

Çoğunlukla Kaynaştırıcı Uygulama grubundaki katılımcılar P2, P3, P5, P6, P8 ve P9'dur. Bu gruptaki katılımcıların TPAB-P'nin üç pedagogij alanındaki performansları, etkili teknoloji destekli öğretim tasarımları ve uygulamaları içermektedir. Ancak, katılmcıların hazırladığı planların ve uygulamaların geliştirilebilir olduğu belirlenmiştir. Öncelikle, uygulamalarda bazı ön değerlendirme örnekleri ile öğrencilerin önceki bilgilerini, kavram yanılgılarını ve öğrenme ihtiyaçlarını belirlemek için teknoloji kullandıkları tespit edilmiştir. Ayrıca, Powerpoint ya da Glogster ile hazırlanmış poster (P2), Pinterest uygulamasından seçilmiş günlük yaşamda geometrik figürlerin Powerpoint sunumu (P6) ve YouTube'da bir origami videosu kullanılarak (P3) yeni bilgiyle ilişki kurmak için sınıf tartışmaları yapılmıştır. Katılımcılar dersin geri kalanını öğrenci cevaplarına göre düzenlenmiştir. Ancak, bu ön değerlendirmelerde teknolojiler dolaylı olarak kullanılmıştır. Diğer üç katılımcı (P5, P8 ve P9) ise öğrencilerin ön bilgi ve öğrenim ihtiyaçlarını değerlendirmiş, ancak bu aşamada herhangi bir teknoloji desteği kullanmamışlardır.

Çoğunlukla Kaynaştırıcı Uygulama grubundaki tüm katılımcılar, matematik bilgisini ölçmek, değerlendirmek, farklı öğrenci öğrenmelerini belirlemek ve desteklemek için çevrimiçi değerlendirme programlarını kullanarak ders sonu değerlendirmesi yapmıştır. Bu değerlendirmelerde matematik konularının farklı temsillerini içeren farklı problem türleri kullandıkları görülmüştür. Ayrıca, katılımcılar tartışma ortamları oluşturmuş ve değerlendirme programlarının verdiği ayrıntılı geri bildirim raporuna dayanarak sonuçları değerlendirmişlerdir. Ancak, öğretimin iyi uygulanıp uygulanmadığını belirlemek için herhangi bir değerlendirme çalışması yapılmamıştır. Görüşmelerde yalnızca bir katılımcı (P9) teknolojinin öğretimin kalitesini değerlendirmek için kullanılabileceğini belirtmiştir.

Katılımcılar sınav sorularının oluşturulmasında ve sınavların uygulanmasında bazı pedagojik yöntemleri dikkate almışlardır. Powerpoint sunumuna, YouTube videosuna veya çevrimiçi değerlendirme programlarına göre hazırlanmış yönlendirici ve yoruma dayalı sorular sorarak etkileşimli sınıf tartışmaları oluşturmuş ve yönetmişlerdir. Gruptaki tüm katılımcılar yeni konuyla bağlantılı olan ön bilginin, öğrenme gereksinimlerinin ve kavram yanılgılarının belirlenmesinin öneminin farkında olup sınavları hazırlarken ve uygularken çevrimiçi değerlendirme programlarının faydalı özelliklerini kullanmışlardır. Sınavlardaki sorular arasında geometrik şekillerde yükseklik (P2), kelime problemleri (P6), farklı soru türleri (P3 ve P6) ve çeşitli temsiller (P5 ve P8) yer almıştır. Ayrıca, katılımcılar çoktan seçmeli, doğru-yanlış ve açık uçlu sorular oluşturmuş, bazı sorulara fotoğraf eklemiş, sorulardaki resimlerin boyutu, soruların zorluk derecesi, soruların çözümü için verilen süre, sınavın hazırlanmasında öğretmen tarafından hazırlanmış sınavdaki geri bildirimler gibi sınavlarla ilgili ayarları başarılı bir şekilde yönetmişlerdir.

Çoğunlukla Kaynaştırıcı Uygulama grubundaki katılımcılar, öğrenci merkezli etkinlikleri içeren teknoloji destekli dersler planlamış ve uygulamıştır. Etkinlikler, öğrenmeyi kolaylaştırmayı ve aktif katılımı arttırmayı amaçlayan işbirlikli bir ortamda yürütülmüştür. Ayrıca, teknoloji kullanımı ile öğrencilerin kendi bilgilerini yapılandırmalarının teşvik edilmesi amaçlanmıştır. Örneğin P8, öğrencilerin farklı kareler oluşturabilecekleri, bu karelerin çevrelerini ve alanlarını hesaplayabilecekleri ve bir karenin çevresini bulmak için genel kuralları belirleyebilecekleri dinamik bir ortam sağlamak için akıllı tahta üzerinde izometrik arka plan kullanmayı planlamıştır. P6 ise sanal gerçeklik programlarını ve GeoGebra'yı kullanarak öğrencilerin prizmalar oluşturup prizmaların özelliklerini araştırmasını sağlamayı amaçlamıştır.

Katılımcılar hazırladıkları planlarını ve mikro öğretimlerini görüşmelerde teknoloji desteğinin eksikliği bakımından eleştirmişlerdir. Özellikle katılımcıların karenin çevresi ve alanı, dörtgenlerin özellikleri ve prizmalar gibi konuların öğretilmesi ve öğrenilmesi için GeoGebra programını ve matematik konuları hakkındaki etkinlik fikirleri, posterler veya resimler gibi güncel materyallere ve tasarımlara kolayca ulaşabilmek için Pinterest uygulamasını tavsiye ettikleri görülmüştür. Ayrıca kavramların görselleştirilmesini, soyut kavramların somutlaştırılması ve öğrencilerin kendi öğrenmelerini çeşitlendirmek ve onları bu anlamda teşvik etmek için Pinterest, YouTube videoları, çevrimiçi oyunlar, çevrimiçi manipülatifler ile Powerpoint sunumunda materyaller ve resimler kullanılması katılımcılar tarafından sıklıkla öneri olarak verilmiştir.

Bu gruptaki katılımcıların planlama ve tasarım performanslarının uygulama performanslarına göre daha iyi olduğu tespit edilmiştir. Ayrıca, akıllı tahta ve GeoGebra gibi teknolojilerin entegrasyonu ile ilgili plan ve önerilerinin, öğrenci merkezli bir ortamda kavramları sorgulama ve öğrenmeyi kolaylaştırma amaçlı olduğu anlaşılmıştır. Katılımcılar, öğretimi geliştirme amacıyla çeşitli teknolojilerin kullanımını önermelerine rağmen, bu teknolojilerin entegrasyonunun gerekliliğini ve etkililiğinin farkına mikro öğretim videolarını izledikten ve akran değerlendirme formlarını okuduktan sonra varmışlardır. Bu nedenle mikro öğretimlerinde kullandıkları teknolojilerin yetersiz olduğu belirlenmiştir.

Grup 3: Çoğunlukla Yansıtıcı Uygulama

Bu gruptaki katılımcılar P1 ve P11'dir. Çoğunlukla Yansıtıcı Uygulama grubundaki katılımcılar, ders planlarında ve görüşmelerde ölçme ve değerlendirme için teknolojilerin ustaca ve stratejik kullanımlarını yansıtan fikirler sunmuşlardır. P11i öğrencilerin geometrik şekillerin özellikleriyle ilgili önceki bilgilerini ortaya çıkarmış ve bu bilginin yeni öğreteceği konu olan paralelkenarın özellikleri ve alanı konusuyla bağlantısını kurmuştur. Ayrıca P11, GeoGebra'da öğrencilerin kavramlarla ilgili eksiklerini tespit etmek için bir etkinlik hazırlamış ve öğretimini buna göre şekillendirmiştir. P1, çevrimiçi değerlendirme programları yoluyla öğrencilerin kavram yanılgılarını belirlemenin öğretimin etkililiği bakımından önemli olduğunu da vurgulamıştır. P1 ve P11 ders sonunda yaptıkları değerlendirmelerde Socrative programını kullanmışlardır. P1, öğrencilerin aktif katılımını arttırmak, öğrencileri bireysel performansları hakkında bilgilendirmek ve öğretmenlerin öğretimin etkililiği hakkında bilgilendirmek için Socrative programının uygun olduğunu belirtmiştir. P1 ve P11 Socrative’in öğrencilerin performansıyla ilgili raporunu değerlendirme için uygun bulmuşlardır. P1 raporları öğrencilerin performansını değerlendirmek için kullanabileceğini ve hem öğretmenleri hem de velileri bu anlamda bilgilendirebileceğini belirtmiş; P11 ise öğretmenlerin yanlış cevapları inceleyerek öğrencilere geri bildirim vermesini önermiştir.

Katılımcılar teknolojileri öğrencilerin öğrenmelerini geliştirmek için ve hem öğretmenlerin hem öğrencilerin matematiksel bilgiyi keşfetmeleri ve oluşturabilmeleri için kullanmışlardır. Katılımcılar teknoloji entegrasyonunun öğretim becerilerini geliştirdiğini belirtmişlerdir. Ayrıca ders planlarına teknolojiyi anlamlı bir şekilde entegre edebilmek amacıyla katılımcılar müfredattaki matematik kazanımlarını revize etmişlerdir. Uygulamalarda, müfredatta bulunan kazanımlara atıfta bulunulmuş, ancak kazanımlar geleneksel içerikten tamamen farklı bir şekilde yeniden tasarlanmıştır. Bir kavram ile ilgili kazanımlar ayrı ayrı değil, bütün olarak ele alınmıştır. Dahası, katılımcılar kazanımlar arasındaki ilişkileri temsiller kullanarak sunmuşlardır.

Katılımcılar, öğretmenlik uygulaması dersi için işbirliği yapılan ortaokul derslerinde ortaokul öğrencilerinin öğrenme ihtiyaçlarını ve kavram yanılgılarını belirlemişler ve bunları göz önünde bulundurarak teknoloji destekli ders planlarını tasarlamışlardır. Katılımcılar, bir üçgen ve paralelkenarın özelliklerini ve alanını açıkça temsil etmek için GeoGebra'yı uygun ve etkili bir teknoloji olarak gördüklerini belirtmişlerdir. Ayrıca, üçgenin yüksekliğinin yeri ve cebir ekranındaki açının ölçüsü gibi temsilleri birbirleriyle ilişkilendirmişlerdir.

Katılımcılar, hem kendi öğrenmelerini hem de öğrencilerin öğrenmelerini ve matematiksel olguları keşfetmelerini kolaylaştırmak için öğrenci merkezli stratejilerin öneminden bahsetmişlerdir. Katılımcıların gelecekte öğretmen olarak verecekleri derslerle ilgili hedefleri, öğrencilerin GeoGebra'da bilgiyi yapılandırarak ve manipüle ederek matematik öğrenmeleridir. Bu gruptaki katılımcıların GeoGebra ve METK dersine dahil edilen tüm teknolojileri kullanmakta kendilerine güvendikleri ve her teknolojiye özgü güçlü özelliklerden yararlandıkları görülmüştür. Örneğin, P1'in açılar, kenarlar ve üçgenler arasındaki ilişkiyi göstermek için bir üçgeni dinamik olarak oluşturması, konunun teknoloji aracılığıyla öğretiminde etkili bir uygulama olarak nitelendirilmiştir.

Tartışma ve Öneriler

Çalışmadaki katılımcıların başlangıçtaki TPAB-P düzeylerinin 1. Seviyede belirlenmiş olması öğretmenlerin teknolojiyi, öğrenmeyi geliştirmek yerine, içeriği aktarma yönünde kullandıkları şeklinde tartışılmıştır (Harris, Mishra, & Koehler, 2009; Sang, Valcke, van Braak, & Tondeur, 2010; So & Kim, 2009). Ozgun-Koca vd. (2010) çalışmalarında başlangıçta ortaöğretim matematik öğretmen adaylarının teknolojiyi yetersiz ve yüzeysel olarak kullandığını belirtmişlerdir. Benzer bir şekilde, Meagher vd. (2011) ortaöğretim matematik öğretmen adaylarının ilk ders planlarında teknolojiyi yetersiz kullandıklarını tespit etmişlerdir.

Çoğunlukla Basit Benimseme Grubundaki OMÖA, teknoloji entegre ettikleri matematik ders planlarını yapılan görüşmelerde eleştirmişler ve aynı konuyu tekrar öğretecekleri zaman içeriğin teknolojiyle aktarılmasna daha fazla ağırlık vereceklerini ifade etmişlerdir. Bu farklılık, öğretmen adaylarının TPAB ile ilgili bilgilerinin ders planlarındaki TPAB içeriğinden daha yüksek düzeyde olmasından kaynaklanıyor olabilir (bkz. Meagher vd., 2011). Ayrıca bu gruptaki

OMÖA, öğretimin geliştirilmesinde ve öğrenmenin desteklenmesinde teknolojinin gücünü vurgulamışlardır. Bu gruptaki OMÖA'nın TPAB-P hakkındaki bilgi ve uygulamalarında uygun teknoloji seçimi ve içeriğe uygunluk (Graham vd., 2012) bakımından başarılı oldukları görülmüştür. TPAB ile ilgili bilgilerinin yanı sıra, bu gruptaki OMÖA, öğrenci merkezli ortamlarda teknoloji entegre edilmiş ders planları tasarlayamamış ve uygulayamamışlardır. Bu gruptaki katılımcılar öğrencilerin öğrenme güçlüklerini ve ihtiyaçlarınnı göz önünde bulundurma konularında Yeh, Lin, Hsu vd. (2015) tarafından yapılan çalışmada teknolojiye geçiş grubundaki öğretmenlerle benzer özellikler göstermiştir.

Çoğunlukla Kaynaştırıcı Uygulama Grubundaki OMÖA teknoloji ile desteklenmiş etkili uygulamalar hazırlamışlardır. OMÖA'nın, teknolojinin yaygın kullanımının ötesine geçmeleri, onları pedagojik amaçlar için yeniden yapılandırmaları (Peehler & Mishra, 2009) ve pedagojik ihtiyaçlar doğrultusunda teknoloji kullanım amaçlarını yeniden belirleyebilmeleri için beceriler geliştirmeleri gerekmektedir (Koehler, et al., 2011). Bu sonuçlar bu grupta ortaya çıkmıştır.

İlgili alan yazında öğretmen adaylarının teknoloji entegrasyon becerilerinin öğretmen eğitimindeki derslerde geliştirilmesi ve araştırılması ile ilgili çalışmaları içermektedir (bkz. Baran & Uygun, 2016; Graham vd., 2012; Meagher vd., 2011; Meng & Sam, 2013). Benzer şekilde, METK dersi, teknoloji destekli matematik derslerinin tasarlanmasında ve uygulanmasında OMÖA'nın teknolojiye ilişkin bilgi ve uygulamalarının geliştirilmesi ve desteklenmesi için tasarlanmıştır. METK dersinin sonunda, tüm OMÖA daha yüksek yeterlilik seviyeleri sergilemişlerdir ve teknoloji entegrasyon çabalarının TPAB'i oluşturan üç pedagogik alanda derinleştirildiğini göstermiştir. METK dersinin ilkeleri olan dönüşümcü yaklaşım, işbirlikli öğrenme, etkinlik destekli öğrenme ve OMÖA'nın TPAB-P gelişimini destekleyen uygulama tabanlı öğrenme etkili yöntemler olarak belirlenmiştir. Teknoloji kullanılan öğretim materyallerinin tasarlanmasındaki işbirlikli çalışmalar, TPAB'ın gelişimini zenginleştirmektedir (Agyei & Voogt, 2012; Koehler & Mishra, 2005; Koehler, Mishra, & Yahya, 2007, Polly vd., 2010, Tondeur, van Braak, vd., 2012). Dahası işbirlikli çalışma, pratik kullanıma uygun kaliteli materyaller tasarlamayı destekler (Yeh vd., 2015). OMÖA, işbirlikli tasarım etkinliklerine katılarak teknoloji entegrasyon yetkinliklerini geliştirerek, fikirlerini, deneyimlerini ve becerilerini paylaşarak gruplar halinde METK dersinin tüm gerekliliklerini tamamlamış ve uygulamalarını Facebook ders sayfasında çevrimiçi paylaşmışlar ve tartışmışlardır. Teknoloji destekli materyaller tasarlarken her aktivite ve tartışmada birbirleriyle etkileşime girmek, birbirlerinin tasarımlarını teknoloji haftalarında ve akran ve öz değerlendirmelerinde yansıtmak, OMÖA'nın eleştirel düşünme becerilerini tetiklemiştir. Dersteki uygulamalar OMÖA'nın TPAB-P becerilerinin geliştirilmesini ve incelenmesini desteklemiştir. Cavin (2008) tarafından yapılan uygulamaya dayalı TPAB araştırmasında öğretmen adaylarının bir lisans dersindeki teknoloji destekli mikro öğretim deneyimlerinin TPAB seviyelerini geliştirdiği tespit edilmiştir. Öğretmen adayları, işbirlikli çalışmalarının teknoloji ile bütünleşmiş ders tasarımlarını kolaylaştırdığını belirtmiştir (Cavin, 2008).

Çalışmada TPAB çerçevesindeki seviyelere ve pedagogij alanlara ait genel ve matematik ilgili örnek davranışlar ortaya çıkmıştır. Genel ya da matematik alanında TPAB çalışmaları yürütmek isteyen araştırmacılar bu çalışmanın sonuçlarını benzer ortamlardaki davranışlarla analiz etmek ve doğrulamak için kullanmaları ilgili çalışmalara yol gösterebilecek önemli bir katkıdır. Bu çalışmanın bir başka katkısı titizlikle tasarlanmış ve uygulanmış ayrıca öğretmen adaylarında TPAB gelişimi sağladığı ortaya çıkmış bir lisans dersi örneğini ayrıtılarıyla sunmasıdır. Dört tasarım ilkesine dayanan bir TPAB geliştirme dersinin tasarımı ve uygulanması, birçok amaca hizmet eden çeşitli teknolojileri kapsamakta ve tek bir matematik konusuna odaklanmak yerine tüm ortaokul matematik içeriğini kapsamaktadır. Bu nedenle, öğretmen adayları için teknolojinin etkili bir şekilde entegre edilmesine örnek bir model olarak düşünülebilir. Bu çalışmanın amacı, OMÖA'nın TPAB becerilerini geliştirmek ve değerlendirmek için en iyi ders modelini ortaya koymaktan ziyade öğretmen eğitimcilerinin bu konuya ilgisini çekmek için bir yaklaşım örneği sunmaktır. Artan TPAB-P seviyeleri OMÖA'nın üzerindeki METK dersinin olumlu etkisini göstermiştir. METK dersinin prensipleri, içeriği ve uygulama detaylarının, benzer amaçlar doğrultusunda bir dersin nasıl geliştirilebileceği konusunda araştırmacıların yeniden düşünmesi için dikkatlerini çekebileceği düşünülmektedir.

Dördüncü seviyeyi temsil eden Çoğunlukla Yansıtıcı Uygulama grubundaki katılımcı sayısının düşük olması, katılımcıların geri kalanının teknoloji entegrasyonu becerilerinin bu düzeye çıkarılması için daha fazla uygulamaya ihtiyaç olduğunu göstermiştir. Öğretmen adaylarının teknoloji entegrasyon becerilerinin gelişimine ve TPAB gelişimine odaklanan çalışmalarda öğretmen eğitim programlarında öğretmen adaylarına sunulan özgün deneyimlerin önemine dikkat çekilmektedir (Tondeur, van Braak vd., 2012). Gelecek çalışmalarda, İnternet bağlantısı, akıllı tahtalar ve bilgisayar laboratuarları gibi teknolojilerle donatılmış okullar, öğretmen adaylarına pratik becerilerini artıracak özgün deneyimler sağlamaları için seçilebilir.

Bu çalışma, OMÖA'nın eğitime teknoloji entegrasyonu yeterliklerini geliştirmeyi amaçlayan ve tek bir derste elde edilen ümit verici sonuçlar ortaya çıkarmıştır. Bununla birlikte, tüm OMÖA TPAB-P ile ilgili bilgi ve uygulama açısından seviye 4 olan hedef seviyesine ulaşmamıştır. Öğretmen adaylarının teknoloji entegrasyon becerilerinin gelişmesi için birden fazla derste desteklenmeleri gerekmektedir (Akyuz, 2016; Chai vd., 2013; So & Kim, 2009). Ancak bu durumda tüm öğretmen adaylarının amaçlanan TPAB-P yeterlilik seviyesine ulaşması beklenebilir. Bu nedenle, öğretmen yetiştirme programlarının içeriği daha sistematik bir şekilde gözden geçirilmelidir (So & Kim, 2009).

APPENDIX O: CURRICULUM VITAE

PERSONAL INFORMATION

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EDUCATION

Degree	Institution	Year of Graduation
MS	METU Secondary Science and Mathematics Education	2010
BS	Baskent University Elementary Mathematics Education	2007
High School	TED Ankara College	2003

WORK EXPERIENCE

Year	Place	Enrollment
2008 - Present	Baskent University, Ankara	Research Assisstant
2006 - 2006	Freeze Frame, Discovery Cove, Orlando, FL, USA	Photographer

FOREIGN LANGUAGES

Advanced English

PUBLICATIONS

JOURNAL ARTICLES

Yiğitcan-Nayir, Ö., Kurt-Erhan, G., ***Koştur, M.***, Türkoğlu, H. ve Mirasyedioğlu, Ş. (2017), Investigating the Readiness of Students in Primary Teacher Education Program through Verbal, Model, and Mathematical Representations of Number Sets, *Turkish Journal of Computer and Mathematics Education, 9*(2).

Koştur, M., ve Yılmaz, A. (2017). Technology Support for Learning Exponential and Logarithmic Functions. *Ihlara Eğitim Araştırmaları Dergisi*, *2*(2), 50-68.

Koştur, M. ve Türkoğlu, H. (2017). Ortaokul Matematik Öğretmenlerinin Matematik Derslerinde Akıllı Tahta Kullanımına İlişkin Görüşleri, *Başkent University Journal of Education, 4*(1), 84-98.

CONFERENCE PAPERS

Yiğitcan-Nayir, Ö., Kurt-Erhan, G., ***Koştur, M.***, Türkoğlu, H. ve Mirasyedioğlu, Ş. (2017). *Sınıf Öğretmenliği Öğrencilerinin Sayı Kümelerine İlişkin Hazırbulunuşluklarının, Sözel, Matematiksel ve Model İfadeleriyle İncelenmesi*, Turkish Computer and Mathematics Symposium 2017 (TÜRKBİLMAT-TURCOMAT), Afyon, Turkey (Proceedings).

Kurt-Erhan, G., ***Koştur, M.*** (2017). *Pre-Service Elementary Mathematics Teachers' Self-Reflections about Their First Teaching Practices,* European Conference on Educational Research 2017 (ECER – EERA), Copenhagen, Denmark.

Güray, Ş., Kılıçoğlu, Ş. ve ***Koştur, M.*** (2015). *İlköğretim ve Ortaöğretim Matematik Öğretmen Adaylarının Matematik Kavramlarını İlişkilendirmeleri,* International Eurasian Conference on Mathematical Sciences and Applications 2015 (IECMSA), Atina, Yunanistan.

Kılıçoğlu, Ş., Güray, Ş. ve ***Koştur, M.*** (2015). *İlköğretim ve Ortaöğretim Matematik Öğretmen Adaylarının Matematik Kavram Bilgisinin İncelenmesi,* International Eurasian Conference on Mathematical Sciences and Applications 2015 (IECMSA), Atina, Yunanistan.

Koştur, M. (2015). *The Views of Pre-Service Elementary Mathematics Teachers on the Use of Interactive White Boards in Elementary Mathematics Courses,* European Conference on Educational Research 2015 (ECER – EERA), Budapest, Hungary.

Kaplan, M., Avcu, S. ve Bulut, S. (2012). *Prospective Mathematics Teachers' Mathematical Problem Solving Beliefs*, European Conference on Educational Research 2012 (ECER – EERA), Cadiz, Spain.

Kaplan, M. ve Çakıroğlu, E. (2012). *Prospective Mathematics Teachers' Use of a Graphing Calculator While Working on Exponential and Logarithmic Tasks*, European Conference on Educational Research 2012 (ECER – EERA), Cadiz, Spain.

Kaplan, M., Çetinkaya, B. ve Erbaş, K. (2011). *İlköğretim Matematik Öğretmen Adaylarının Grafik Hesap Makinesi Kullanımında Karşılaştıkları Zorluklar ve Çözüm Önerileri*, 10. Matematik Sempozyumu, İstanbul (Bildiri Özetleri Kitabı).

Yıldırım, B., Koğar, H., Kostur, H. İ. ve ***Kaplan, M***. (2010). *Öğretmen Adaylarının Öğretmenlik Uygulaması Dersinde Yaşadıkları Sorunların Değerlendirilmesi*, 19. Ulusal Eğitim Bilimleri Kurultayı, Lefkoşa, 197-198 (Bildiri Özetleri Kitabı).

Kaplan, M., Keleş, B. ve Yılmaz, K. (2006). *Matematik Dünyasında Eğlence Parkuru,* Matematikçiler Derneği Matematik Etkinlikleri, 5. Matematik Sempozyumu, Ankara, Türkiye.

SEMINARS, PROJECTS AND WORKSHOPS

Scholar Researcher: 01.03.2014 – 01.03.2015 TÜBİTAK Project No: 111K545
Developing a Screening Tool to Determine Dyscalculia of Turkish Children Aged between 6 - 11

Scholar Researcher: 01.2011 – 07.2012 TÜBİTAK Project No: 109K559
Psycho-Social Development of Adolescents in Turkey: A Profile and Support Study

Origami Stand Organizer: European Researchers’ Night, İzmir, Turkey, September, 2012.

Question Preparation Committee: I. - VII. Mathematics League, Maya College, 2011-2018.

Attendant: Teaching and Learning Techniques Seminar, Ayşeabla Elementary School, Ankara, Turkey, 2010.

Symposium Organization Committee: National Symposium of Teacher Training Issues in Turkey, Başkent University, Ankara, 12-13 November, 2009.

SCHOLARSHIPS

10 / 2007 – 10 / 2009: TUBITAK 2211 Graduate Scholarship Programme

TEZ FOTOKOPİSİ İZİN FORMU

<u>ENSTİTÜ</u>

Fen Bilimleri Enstitüsü ☐

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Uygulamalı Matematik Enstitüsü ☐

Enformatik Enstitüsü ☐

Deniz Bilimleri Enstitüsü ☐

<u>YAZARIN</u>

Soyadı : Koştur
Adı : Merve
Bölümü : İlköğretim

<u>TEZİN ADI</u> (İngilizce): Promoting and Investigating Pre-Service Middle School Mathematics Teachers' TPACK-Practical Development in the Context of an Undergraduate Course

<u>TEZİN TÜRÜ</u> : Yüksek Lisans ☐ Doktora ■

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<u>TEZİN KÜTÜPHANEYE TESLİM TARİHİ</u>: