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THE DEVELOPMENT OF TPACK OF A PROSPECTIVE MATHEMATICS TEACHER IN THE CONTEXT OF TEACHING PRACTICES COURSE

MATEMATİK ÖĞRETMEN ADAYININ ÖĞRETMENLİK UYGULAMASI DERSİ BAĞLAMINDA TPAB GELİŞİMİ

Esra YILDIZ[1], Erdinç ÇAKIROĞLU[2]

ÖZ: Çalışmanın amacı, bir matematik öğretmen adayının öğretmenlik uygulaması dersi kapsamında bir kolaylaştırıcı eşliğinde gerçekleştirdiği teknoloji destekli matematik eğitimi uygulamalarının onun Teknolojik Pedagojik Alan Bilgisi'ne (TPAB) katkısını nitel olarak araştırmaktır. Çalışmanın katılımcısı bir 4. sınıf matematik öğretmen adayıdır. Öğretmen adayı, uygulamalar sırasında araştırmacı tarafından gözlemlenmiş ve her bir ders uygulamasının öncesi ve sonrasında uyguladığı derse yönelik yansıtıcı görüşleri alınmıştır. Veriler, beş aşamalı TPAB değerlendirme rubriği kullanılarak analiz edilmiştir. Analiz sonuçları, öğretmen adayının çalışma süresince TPAB düzeyinde artan bir değişim gösterdiğini ortaya koymuştur. Dersin üç bileşeni - dersin amacı, soruların niteliği ve öğretmen adayının kullandığı öğretim yöntemi - TPAB düzeyindeki değişimi belirlemek için önemli ipuçları sağlamıştır. Sonuçlar, teknoloji destekli öğretim deneyimi ve yansıtıcı düşünme süreçlerinin, öğretmen adaylarının TPAB düzeylerinin geliştirilmesi için gerekli olduğunu göstermektedir. Ayrıca, öğretmen adayının teknolojiyi ders uygulamaları sırasında aşamalı olarak öğrenci farkındalığını artırmak, kavramsal anlayışlarını sorgulamak ve matematik öğrenmelerini teşvik etmek için kullandığı tespit edilmiştir.

Anahtar sözcükler: TPAB, Öğretmenlik Uygulaması Matematik öğretmen eğitimi, GeoGebra, Teknoloji entegrasyonu

ABSTRACT: The aim of the study is to qualitatively investigate the contribution of technology-supported mathematics education practices conducted by a mathematics teacher candidate during a teaching practicum course, facilitated by an instructor, to their Technological Pedagogical Content Knowledge (TPACK). The participant of the study is a 4th-grade mathematics teacher candidate. The teacher candidate was observed by the researcher during the practices, and reflective views on each lesson implementation were obtained before and after each teaching session. The data were analyzed using a five-stage TPACK assessment rubric. The analysis results indicate an increasing change in the participant's TPACK level over the course of the study. The three components of the lesson - the objective of the lesson, the nature of the questions, and the teaching method used by the teacher candidate - provided important clues to determine the change in TPACK level. The results demonstrate the necessity of technology-supported teaching experiences and reflective thinking processes for the development of teacher candidates' TPACK levels. Additionally, it was found that the teacher candidate gradually used technology to increase student awareness, challenge their conceptual understanding, and promote mathematics learning during the teaching practices.

Keywords: TPACK, Teaching practice, Mathematics teacher training, GeoGebra, Technology integration

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[1] Doç. Dr., İstanbul Medeniyet Üniversitesi, İstanbul/Türkiye, esra.yildiz@medeniyet.edu.tr, 0000-0003-2771-4647
[2] Prof. Dr. TED Üniversitesi, Ankara/Türkiye, erdinc.cakiroglu@tedu.edu.tr, 0000-0003-1182-0752
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GENİŞLETİLMİŞ ÖZET

Giriş

Matematik eğitimi teknolojileri (GeoGebra, Geometer's Sketchpad, Tinkerplots, grafik hesap makineleri, Web 2 araçları, artırılmış gerçeklik uygulamaları, yapay zeka teknolojileri vb.), öğrencilerin dikkatini konuya çekmek için kullanılan, sınıf içi etkileşimi artıran, dinamik özellikleri ile öğretimsel deneyler yapılmasına olanak tanıyan ve öğrencilerin kavramsal öğrenmelerini destekleyen önemli araçlardır (Abunda, 2021; da Silva Bueno vd., 2021; Oner, 2020; Papanikolaou vd., 2022). Zbiek (2003) eğitim teknolojilerinin öğretmenin derste rehber rolünü üstlenmesini destekleyeceğini ve böylelikle öğrencilerin matematiksel düşünmelerini ve muhakeme etme becerilerini geliştirmelerine olanak sağlayacağını belirtmiştir. Öğretmen adaylarının, bu teknolojileri etkili şekilde derslerine entegre edebilmeleri ve kullanabilmeleri için Teknolojik, Pedagojik Alan Bilgilerinin (TPAB) geliştirecek teknolojik içerikli derslere ve teknik bilgilerini pedagojik bilgileri ile birleştirmeye olanak tanıyan uygulama fırsatları tanınmasına ihtiyaçları bulunmaktadır (Balgalmis et al., 2015; Niess, 2006; Lyublinskaya ve Kaplon-Schilis, 2022; Zeincher, 2012). Niess et al. (2007), çalışmalarında birbirinden bağımsız olarak verilen teknolojik, pedagojik ve alan bilgilerinin öğretmenlerin eğitim teknolojisi kullanım becerisini geliştirmede yeterli olmadığını belirterek, öğretmenlerin TPAB'lerini geliştirmek için gerçek sınıf ortamında yapılan teknoloji-destekli uygulamaların önemine vurgu yapmaktadır (Niess et al., 2007). Öğretmenlik Uygulaması dersi öğretmen adaylarının kendilerini ilk defa bir öğretmen olarak algıladıkları, kendi tasarladıkları teknoloji destekli ders planlarını uygulama şansına sahip oldukları, sınıf ortamının doğasını gözlemleme ve okul kültürünü keşfetme fırsatına sahip oldukları bir derstir (Hur, Cullen ve Brush, 2010; Niess, 2006; Mouza ve Wong, 2009). Öğretmenlik Uygulaması dersi, öğretmen adaylarının o döneme kadar biriktirdikleri öğretmenlik bilgilerini kullanarak kendi öğretim tasarımlarını yaptıkları ve belki de ilk defa TPAB uygulamaları yapma imkânı buldukları bir ders olarak değerlendirilebilir. Öğretmen adayları Öğretmenlik Uygulaması dersi kapsamında, yaptıkları ders tasarımları üzerine tartışma ve değerlendirme yaparak öğretmenlik deneyimi ile ilgili farkındalık kazandıkları alan yazında yapılan çalışmalarda ortaya konulmaktadır (Harris, 2008; Niess, 2006; Zeichner, 2008).

Yetmişli yılların başında Schön tarafından ortaya atılan yansıtıcı düşünme aktiviteleri de öğretmen eğitiminde kullanılan, Öğretmenlik Uygulaması dersinin etkililiğini destekleyici bir metot olarak kullanılmaktadır (Pakman, 2000). Schön (1987) yaşadıkları deneyimlerle ilgili olarak bireylerle görüşmeler yapılmasını ve bu deneyimin kendileri için olumlu ve olumsuz özelliklerinin farkettirilmesinin önemine vurgu yapmaktadır. Bu bağlamda, bir örnek olay incelemesi olan bu çalışma, öğretmen adaylarının gerçek sınıf ortamında uyguladıkları teknoloji destekli öğretim deneyimleri ve bu deneyimlerle ilgili olarak yapılan yansıtıcı görüşmelerin, TPAB gelişimlerine olan katkılarını araştırmak amacıyla planlanmıştır. Bu çalışmanın araştırma soruları;

1. Teknoloji destekli ders uygulamalarının, yansıtıcı görüşme tekniği kullanılarak desteklendiği bir Öğretmenlik Uygulaması dersi sürecinde öğretmen adayının TPAB düzeylerinde nasıl bir değişim gözlenmektedir?
2. Öğretmen adayının TPAB düzeyi hangi etkenlere bağlı olarak değişmektedir?

Metot

Yansıtıcı düşünme görüşmeleri ile zenginleştirilmiş Öğretmenlik Uygulaması dersi bağlamında, matematik öğretmeni adayının TPAB gelişim sürecinin incelendiği bu çalışma bir örnek olay incelemesi niteliğindedir. Nitel araştırma yöntemlerinden biri olan örnek olay incelemesi, sınırlı bir sistem (Creswell, 2007) olarak tanımlanır ve bir durum ve katılımcı hakkında detaylı bilgi edinmeyi amaçlar (Merriam, 1998). Bu çalışma kapsamında öğretmen adayının matematik öğretimine teknolojiyi entegre etme stratejilerindeki gelişimine, karşılaşılan sorunları çözme yöntemlerine ve bu süreçteki yansımalarına dair kanıtlar, görüşmeler, gözlem notları, öğretmen adayının hazırladığı ders planları ve yansıtıcı raporları özellikle araştırmacı tarafından toplanan öğretmen adayının ders uygulamalarının gözlem notu ve video kayıtları nitel very toplama yöntemleri ile toplanmıştır.

Katılımcı

Araştırmanın katılımcısı, İç Anadolu Bölgesindeki bir devlet üniversitesinin Eğitim Fakültesi İlköğretim Matematik Öğretmenliği Bölümü 4. sınıf öğrencilerinden, teknoloji destekli matematik öğretimi dersini alan ve Öğretmenlik Uygulaması dersine devam eden bir kadın öğrencidir.

Veri Analizi

Veriler nitel veri analizi yöntemleri ile analiz edilmiştir. Ders planı ve ön görüşme verileri, teknoloji destekli dersin uygulandığı sınıf veya bilgisayar laboratuvarı ortamını betimlemek, teknolojinin kullanma amacını açıklamak, amacı ile kullanılmıştır. Video kayıtları ve gözlem verileri ise, öğretmen ve öğrencilerin ders içerisindeki rollerini açıklamak, öğrenci-öğretmen diyalogları ile ilgili örnekler sunmak, öğretim yöntemleri ve eğitim teknolojisinin nasıl kullanıldığı hakkında detaylı bilgi vermek amacıyla analiz edilmiştir. Ek olarak, öğretmen adayının içinde bulunduğu sürece dair hazırladığı yansıtma yazıları, uygulama süreci hakkındaki genel düşüncelerini rapor etmek için kullanılmıştır. Katılımcının TPAB seviyesindeki değişimler ise alan uzmanları tarafından geliştirilen TPAB seviyeleri rubriği (Lyublinskaya, & Kaplon-Schilis, 2022) ile değerlendirilmiştir. Bu rubrik uygulama sırasında aday öğretmenlerin kullandıkları ders anlatım yöntemleri, öğrendikleri dinamik geometri programı yardımıyla ürettikleri öğretim materyallerinin niteliği, teknoloji kullanım becerilerinin gelişimi, öğrencilerle olan ilişkileri ile ilgili değerlendirmeler içermektedir.

Bulgular

Çalışmanın bulgularına göre Teknoloji destekli ders uygulamalarının, yansıtıcı görüşme tekniği kullanılarak desteklendiği bir Öğretmenlik Uygulaması dersi sürecinde öğretmen adayının TPAB düzeylerinde aşamalı bir artış gözlenmiştir. Öğretmen adayının TPAB seviyesindeki değişimleri belirleyen üç bileşen; öğretmen adayının teknolojiyi öğretimde kullanma amacı, ders sırasında öğrencilere yönelttiği düşünme sorularının niteliği ve kullandığı öğretim yöntemleri olarak belirlenmiştir. Öğretmen adayının, sınıf içi uygulamalarda deneyim kazandıkça, teknoloji kullanım amacının değiştiği gözlenmiştir. Örneğin, ilk derste öğretmen adayının dinamik geometri programı ile bir problemi modellediği ve programı daha çok öğrencileri strateji geliştirme süreçlerini desteklemek ve çözüme yönelik ipucu vermek amaçlı kullandığı gözlenmiştir. Etkinliği öğrencilerin problemi çözmesini destekleyici nitelikte olmasına rağmen, uygulama sırasında, oldukça sınırlı sayıda öğrenciye fırsat sunarak derse katılmalarını sağlamıştır. Hazırladığı soruların önemli bir bölümünün öğrencilere yöneltilememesi, yöneltilen soruların cevapları için ise öğrencilerin düşünmelerine olanak tanınmadan cevaplaması nedeniyle dersin ders değerlendirme kriterleri göz önünde bulundurulduğunda kritelerin tam olarak sağlanmadığı bir ders olduğu sonucuna ulaşılmıştır. Konu ile ilgili olarak öğretmen adayı ile yapılan yansıtıcı görüşmede bu durum sorgulanmış ve öğretmen adayının farkındalık kazanması sağlanmaya çalışılmıştır. Öğretmen adayı ikinci dersinde, GeoGebrayı yine bir gerçek hayat problemini modellemek için kullandığı ancak bu defa, problemin çözümüne yönelik ipucu vermek yerine, öğrencilerin kendi hızlarında problemi keşfetmeleri ve çözümü tahmin etmeleri için çalışabilecekleri iki deneme etkinliği oluşturduğu görülmüştür. İkinci ders uygulamasında öğretmen adayı dersi bilgisayar laboratuvarında gerçekleştirmiş ve her bir öğrenciye çözüme yönelik deney yaparak strateji geliştirmesine ve çözümünü keşfetmesine olanak tanımaya çalışmıştır. Son derste ise öğretmen adayı farklı örnekler kullanarak eğitim teknolojisiyle en etkili dersini gerçekleştirmiştir. Ders uygulamasının öncesi ve sonrasında yapılan yansıtıcı görüşmelerin TPAB gelişimine katkıda bulunmasının yanı sıra, sonraki uygulamalarda önceki uygulamalarda yapılan hataların tekrarlanmasını önleyici olduğunu söylemek mümkündür.

Tartışma ve Sonuç

Bu çalışma, öğretmen adaylarının teknoloji destekli ders uygulamaların yansıtıcı görüşme teknikleri ile desteklendiğinde, öğretmen adayının TPAB seviyelerini geliştirme açısından olumlu bir değişime katkı sağladığını ortaya koymaktadır. Hixon ve So (2009) da benzer şekilde teknoloji destekli ders uygulamalarının PMT'lerin TPAB'lerini geliştirmek için kritik derecede önemli olduğunu belirtmişlerdir. Mudziri (2012) çalışmasında öğretmen adayının ilk uygulamasında teknolojiyi amacından bağımsız olarak teknik anlamda nasıl kullanacağına odaklanmışken, sonraki ders uygulamalarında teknolojiyi daha çok öğrencilerin matematik kavramlarını keşfetmelerine olanak sağlama amacıyla kullandıklarını belirlemiştir. Alan literatüründeki benzer çalışmalar incelendiğinde, öğretim etkinlikleri sırasında öğretmen adaylarının ders tasarımlarını gerçek sınıf ortamında uygulama fırsatı bulduklarında,

tasarladıkları etkinliğin sınıf içi uygulanabilir özellikler taşıyıp taşımama açısından öz değerlendirme yapabilir hale geldiklerini belirtmektedir (Hixon & So, 2009; Zeichner, 2010). Mouza ve Karchmer-Klein (2013), teknoloji entegrasyonu, sınıf içi etkinliklerin tasarlanması, gerçekleştirilmesi ve üzerine düşünülmesinin Matematik Öğretmen Adaylarının (MÖA) teknoloji, içerik ve pedagoji arasındaki bağlantıları farketmeye başlamalarının etkili bir yolu olduğunu belirtmektedir. Bu çalışma, öğretmen adaylarının, teknoloji destekli gerçek sınıf ortamlarında gerçekleştirdikleri öğretim deneyimlerinin öğretmen adaylarının eğitim teknolojisini kullanma amaçlarının aşamalı olarak değiştiğini göstermiştir. Bu araştırmanın sonuçları, teknoloji-destekli matematik eğitimi uygulamalarının uzman gözetiminde yapılması ve sonrasında dersin olumlu ve olumsuz yönleri üzerine tartışılmasının TPAB gelişimi açısından önemli olduğunu göstermiştir. Sonuç olarak öğretmen adaylarının teknoloji destekli öğretim uygulamaları deneyimlemelerinin TPAB'lerini geliştirdiğini söylemek mümkündür (Kaplon-Schilis & Lyublinskaya, 2016; Niess; 2008; Oner, 2020; Papanikolaou et al., 2022; Stapf & Martin, 2019).

INTRODUCTION

A number of studies have been conducted to illustrate the effectiveness of educational technologies in teaching of mathematics (Abunda, 2021; da Silva Bueno et al., 2021; Delgado et al., 2015; Kim & Baylor, 2008; Lyublinskaya & Du, 2022a; Lyublinskaya & Du, 2022b; Mouza et al., 2017; Niess & Gillow-Wiles, 2021; Stapf & Martin, 2019). The mathematics education technologies (i.e. dynamic geometry, especially GeoGebra, Geometer's Sketchpad, Tinkerplots, graphing calculators, e-learning environments, appleths) are required in raising students' conceptual understanding, take their attention to the content, motivate them to learn (Abunda, 2021; Acikgul & Aslaner, 2020; da Silva Bueno et al., 2021; Hollebrands, 2007; Kaput & Thompson, 1994; Koh, 2019; Oner, 2020; Papanikolaou et al., 2022; Peressini & Knuth, 2005). Teacher education programs need to include the specific technologies in their curriculum to develop techno-pedagogical knowledge and skills (Thompson & Kersaint, 2002; Balgalmis, 2013). They should give opportunity to Pre-Service Mathematics Teachers (PMTs) to participate in numerous experiences to engage in investigating, thinking, planning, practicing, and reflecting related to educational technologies for 21st century instruction (Niess, 2006; Lyublinskaya & Kaplon-Schilis, 2022; Balgalmis et al., 2015).

The effective integration of technology necessitates the conversion of knowledge into techno-pedagogical formats. Teachers must possess the technological proficiency to translate knowledge into technology-infused activities employing the most suitable instructional strategies for the subject matter as Shulman (1986) argued in terms of PCK. Technological Pedagogical Content Knowledge (TPACK), which encompasses the incorporation of educational technology into the teaching of specific subject matter topics, was conceptualized by Koehler and Mishra in 2005, building upon Pierson's (2001) research. TPACK comprises three fundamental constructs of teacher knowledge: content knowledge (CK), referring to knowledge of the subject matter; pedagogical knowledge (PK), pertaining to knowledge of teaching methods and learning processes; and technological knowledge (TK), involving knowledge of technology and technological tools. Additionally, there exist four other types of knowledge, derived from the intersections between technological, pedagogical, and content knowledge. These four additional types of knowledge are: technological content knowledge (TCK), encompassing the knowledge of leveraging technology to convey subject matter concepts; technological pedagogical knowledge (TPK), concerning the application of technology to employ diverse teaching methodologies; and pedagogical content knowledge (PCK), encompassing knowledge of effective teaching methods (Koehler & Mishra, 2009; Koh & Divaharan, 2011).

Transforming theoretical knowledge into practice is a controversial issue (Bobis, 2007). PMTs have concerns about their ability to teach before they have experience in real classroom environment and teaching practice is an occasion to be challenged PMTs' teaching ability throughout their programme (Howey & Zimpher 1996; Knowles & Cole, 1996; Nordin et al., 2013; Yeh et al., 2015). In teaching practice PMTs have the chance to observe the nature of classroom settings in a real classroom context and explore school culture and create a sense of self as a teacher (Hur, Cullen, & Brush, 2010; Niess, 2006; Mouza & Wong, 2009). Because teaching practice provides a space for PMTs to practice teaching activities that integrate technology, content, and pedagogy, Zeincher (2012) claimed it helps PMTs develop professional vision and skills.

Teaching practice course is a crucial setting for connecting theory and practice (Darling-Hammond, 2010; Wenthworth et al., 2004; Zeichner, 2008). Frequently, the professed pedagogical beliefs of PMTs are incongruent with their actual teaching practices (Lawless & Pellegrino, 2007). The utilization of teaching practice courses in teacher training programs holds promise for cultivating novel insights into technology integration in mathematics education. PMTs must be encouraged to restructure their subject matter content and utilization of educational technology in accordance with the evolution of educational tools and the subject itself (Niess, 2006). The execution of technology-based lessons in practical settings is crucial for the development of PMTs' TPACK; the formulation of a technology-based activity and its subsequent implementation in a real classroom environment provide PMTs with the opportunity to refine their skills and glean insights from practice (Darling-Hammond, 2010; Hixon & So, 2009; Mouza & Wong, 2009). Teaching practice courses have demonstrated efficacy in enabling educators to recognize, differentiate, discuss, integrate, and execute TPACK activities within curriculum standard-based instructional designs (Harris, 2008).

This study aimed to provide information about the contribution of the teaching practice course on PMT's knowledge of technology. The main goals of this study were as follows: 1) to examine the contribution made by teaching practice course and reflection-on-action processes to PMTs' TPACK levels in different teaching experiences—specifically designing and preparing teaching aids, and; 2) To measure the extent of the changes and adaptations to participant's TPACK through of the implementation of three technology-based lessons in a teaching practice course. With this aim, the following central research questions guided this study:

1. To what extent do PMT develop their TPACK through the implementation of technology-based mathematics lessons?
2. What factors have contributed to the enhancement of TPACK levels?

Theoretical Framework

The aim of the study was contributing to the literature on what teachers gain from implementing technology-based lessons in a real classroom context and reflecting on what they learned from their practice. The theoretical framework of this study is centered around Koehler and Mishra's (2005) categorization of techno-pedagogical content knowledge (TPACK). Later, theoretical research continued by defining a five-stage developmental process for TPACK to integrate technology into mathematics education based on Grossman's (1990) four-component PCK named as Five Stages Model (Niess, Lee, & Sadri,

Following the delineation of five developmental stages concerning TPACK, The Association of Mathematics Teacher Educators' (AMTE) technology committee introduced a five-level model to elucidate the incorporation of technology in mathematics teaching and learning in 2009. This model, outlined by Niess et al. (2009), drew upon Rogers's (1995) innovation-decision process model. A graphical representation depicting the five levels of TPACK integration is presented in Figure 1 (Niess et al., 2009, p.10).

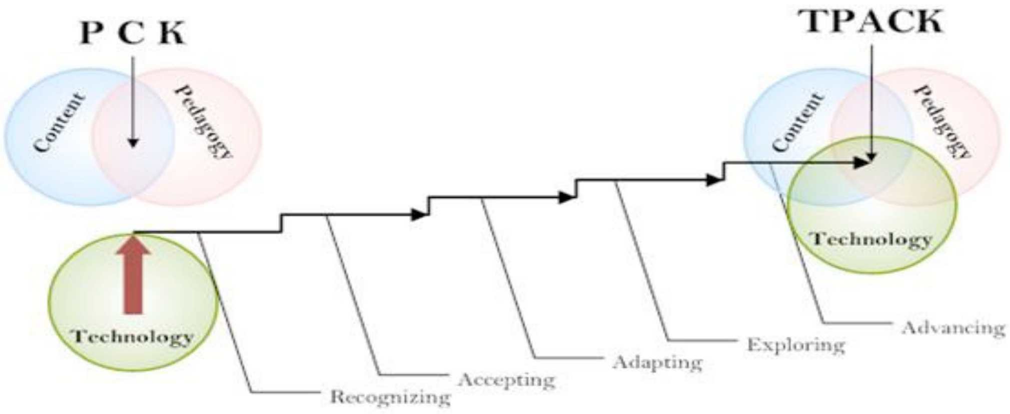


Figure 1. Five Stages for Integrating Technology in Teaching and Learning Mathematics (Niess et al., 2009, p. 10, Source: Reproduced with permission of the first author

This framework offers insights into how teacher training programs can impart to prospective mathematics teachers (PMTs) the conceptualization of teaching with technology, pedagogy, and content (Niess et al., 2009). The stages outlined in the model recognizing, accepting, adapting, exploring, and advancing. The model includes four themes: curriculum and assessment, learning, teaching, and access.

Comprising four main themes—curriculum and assessment, learning, teaching, and access—the model illustrates the progression of teachers as they traverse from one level to the next, with TPACK evolving across each theme with each utilization of educational technology (Niess et al., 2009).

The initial component, "an overarching understanding of the purposes for integrating technology into teaching subject matter topics," pertains to PMTs' instructional decisions and encompasses their grasp of the subject's essence, the critical learning objectives, and the role of technology in facilitating learning. “Knowledge of student understanding, thinking, and learning in subject matter topics with technology” focuses on PMTs' awareness of student cognitive processes when utilizing technology in specific mathematical domains. “Knowledge of curriculum and curricular materials that integrate technology in learning and teaching subject matter topics” pertains to PMTs' knowledge of both the curriculum and technological resources applicable to teaching mathematics. Lastly, “Knowledge of instructional strategies and representations for teaching and learning subject matter topics with technologies” addresses PMTs' ability to tailor their teaching methods to effectively incorporate specific technologies into mathematics instruction (Lyublinskaya & Tournaki, 2012; Lyublinskaya & Kaplon-Schilis, 2022).

This model facilitates the assessment of teachers' proficiency in integrating technology into teaching and offers insights into the knowledge progression of PMTs (McBroom, 2012; Rakes et al., 2022). Lyublinskaya and Tournaki (2012) amalgamated the four components delineated by Niess et al. (2009) with the five-stage developmental process outlined by Niess et al. (2007) to devise a rubric for analyzing the evolution of PMTs' Technological Pedagogical Content Knowledge (TPACK) levels in mathematics education. A framework aimed at cultivating PMTs' TPACK, known as Situated Technology Integration (SiTI) guidelines, was proposed by Hur, Cullen & Brush, (2010). These guideline encompasses facets of TPACK within the broader classroom context, delineating the role of teacher educators in teaching practice courses to foster the development of TPACK in PMTs.

SITI Model

Hur, Cullen and Brush (2012) developed a guideline to improve PMTs’ TPACK as follows.

SiTI Guidelines:

- Provide concrete experiences
- Promote Reaction
- Assist in application
- Create communities of learners
- Develop Technological Pedagogical and Content Knowledge (p. 167).

These guidelines explain the role of teacher educator to develop PMTs’ TPACK. These guidelines were used in the framework implementation process of this study.

Reflection-on-Practice Process

During the 1970s, Schön embarked on investigations into "what makes professional practice effective" (Pakman, 2000, p. 5), culminating in the proposal of the theory of reflective practice in teacher education (Schön, 1983). The conceptual foundation of this framework can be traced back to Dewey's (1933) theory of reflective thought and action. Reflective practice, characterized by the ongoing monitoring of professional actions as a mechanism for professional growth, garnered favor among teacher educators (Osterman, 1990; Vermunt & Verloop, 1999). The primary objective of the reflective process is to enhance educators' understanding of why they employ instructional strategies and how they can refine their pedagogical skills (Lee, 2005). Through reflection, educators discern the rationale behind their chosen instructional methods and identify avenues for enhancing their teaching practices (Lee, 2005). Niess (2006) stated that this practice requires PMTs to notice when, where, and how technology enhanced their teaching. Reporting on their own efforts strengthens their use of technology (Mouza & Karchmer-Klein, 2013). Reflection-on-action takes place after the lesson. Teacher educators raise questions about PMTs’ existing practices, using cases from the lesson, and they gain a clearer understanding of PMTs’ knowledge. Giaimo-Ballard and Hyatt (2012) stated that the reflection process drives PMTs to analyze their own practice, which results in changes in their teaching and how they approach the use of technology as a teaching tool.

METHOD

The Research Design of the Study

The goal of the study was to provide rich descriptions of participant's TPACK development in mathematics within the context of teaching practice course period. The research design of the study is a case study. Case studies are a bounded system (Creswell, 2007), aiming to get in-depth information about a situation and the participant (Merriam, 1998). Data were gathered from four distinct sources: interviews, observational notes, documents provided by the PMT, and videotaped sessions. In terms of data collection, qualitative methods were employed to gather evidence of enhancements in participant's strategies for incorporating technology into mathematics instruction, their approaches to problem-solving, and reflections on this process.

Participant and Data Collection

The participant was a fourth-year PMT enrolled in an undergraduate Elementary Mathematics Education program. Selection of the participant was conducted using purposive sampling, a method enabling the selection of individuals who can offer comprehensive insights into the research question (Patton, 1987; Creswell, 2007). It should be noted that the study's outcomes are not intended for generalization to the broader population. Rather, the research serves as an inquiry and assessment of a PMT's integration of technology in mathematics education during their teaching practice course.

Two benchmarks were taken into consideration during participant selection. The first was enrollment in the technology-based teaching course, because the study investigates the role of this course on techno-pedagogical skill development. The second benchmark was enrollment in the Teaching practice course. Since Meltem took these two couses she has been choosen as a participant of the study. The participant of the study conducted three technology-based lessons at a public middle school. Six face-to-face semi-structured interviews were conducted with the participant: one prior to each teaching session to gauge expectations, and one following each session to evaluate the process and gather self-assessment from the participant. These interviews were conducted in a conversational manner and audio recorded with the participant's consent. The researcher posed questions and allowed ample time for the participant to provide clear responses. Questions were restated or clarified as needed. Throughout the interviews, participant shared her perspectives on the extent to which lesson objectives were achieved, areas for improvement in using dynamic geometry programs effectively, and her plans for future teaching with dynamic geometry. The semi-structured interviews typically lasted around 30 minutes each.

Data Analysis

The data were analyzed using qualitative methods. The lesson plan and pre-interview data were used to describe the classroom or computer lab environment and the aim of the technology-based activity. Video records and observation data were used to give information about the role of the teacher and students, student-teacher dialogues, teaching methods, and the use of educational technology. Post-interview data were used to analyze participant's self-evaluation of the implemented lesson and their plans for the next implementation. In addition, PMT's reflection papers were used to report her general ideas about the implementation process. In analyzing the data, the researcher concentrated on assisting in implementation and developing TPACK guidelines outlined in the SITI Model. Following the participant's development and implementation of her plans in the classroom, the final interview was conducted to encourage and document her reflections on her experiences. A TPACK levels rubric was employed to evaluate the PMT's performance in technology-based lesson implementations.

TPACK Levels Rubric

The data analysis utilized the TPACK levels rubric developed and validated by Lyublinskaya & Kaplon-Schilis (2022) to assess and ascertain PMTs' TPACK level. This rubric, based on the five levels delineated by Niess et al. (2009), evaluates PMTs' utilization of technology in mathematics instruction. These levels encompass recognizing, accepting, adapting, exploring, and advancing, with recognizing representing the initial and lowest level, and advancing reflecting the highest level. Each level of TPACK is accompanied by qualitative descriptors pertaining to four primary components:

- C1: An overarching conception about the purposes of incorporating technology in teaching;
- C2: Knowledge of students' understandings, thinking, and learning with technology;

- C3: Knowledge of curriculum and curricular materials that integrate technology in learning and teaching,
- C4: Knowledge of instructional strategies and representations for teaching and learning with technology.

For the current study, to evaluate PMTs' technology-based lesson implementation performance a rubric developed by Lyublinskaya & Kaplon-Schilis (2022) was used.

Validity of the TPACK Levels Rubric

The TPACK rubric was validated on PMTs, it is appropriate for the study since the participant of the study is a PMT. To ensure consistency across various components within the same level and to delineate the disparities between different levels, the rubric's performance indicators underwent meticulous examination and revision (Lyublinskaya & Kaplon-Schilis, 2022). The internal consistency of the rubric yielded values ranging from 0.951 to 0.968 for its four components, with an overall value of 0.985. This rubric has been employed in prior studies to evaluate participant's TPACK performance, as evidenced by its utilization in studies conducted by Handal et al. (2016), Lyublinskaya & Du (2022), Lyublinskaya & Tournaki (2013), McBroom (2012), Mudzimiri (2012), and Rakes et al. (2022).

Inter-Rater Reliability of the Rubric

To ensure the completion of inter-rater reliability for the lesson implementations, the researcher engaged a second rater, an expert in the content, pedagogy, and technology of the lesson implementations. This individual, possessing over 20 years of experience as a middle school mathematics teacher and holding a master's degree in mathematics education, was tasked with watching the video recordings and lesson descriptions and subsequently rating the data using the TPACK rubric. Prior to the rating process, the researcher provided detailed instructions on how to utilize the rubric and facilitated discussions to elucidate the meaning of each criterion. Furthermore, sample artifacts were assessed and discussed to establish consensus on the criteria of the rubric. Subsequently, the rater independently scored each lesson implementation based on the four components of TPACK. Inter-rater reliability was evaluated using the Pearson product-moment correlation coefficient, a commonly employed statistic in literature for assessing the consistency between independent raters (O'Connor & Joffe, 2020). A threshold of .70 is typically deemed acceptable for reliability using Pearson correlation (Multon, 2010). In the present study, the Pearson correlation coefficient calculated was $r(34) = .73$, $p < .01$, indicating a 73% consistency between the scores provided by the researcher and the rater. In addition, an expert opinion about the data analysis of this study was taken from Lyublinskaya (January-2023). She reviewed the analysis of the study and shared her written opinion about the TPACK levels. According to her opinions, ratings and assessments of the participant has been revised.

Ethical Permissions of the Research

In this study, research ethics principles have been adhered to, and the necessary ethical approvals have been obtained from Middle East Technical University.

RESULTS

The results indicated an observable increase in Meltem's TPACK level over the course of the study. This section provides a summary of the participant's TPACK changes, as observed according to the TPACK levels rubric, by giving specific examples from lesson implementations.

Case Meltem

Meltem implemented three technology based lessons with students at a public middle school. In implementations, she chose objectives aligned with the national curricula and employed dynamic geometry as a teaching tool. The students in all three lessons were the same students.

First Lesson Implementation

Meltem's goal to use technology was to model a dynamic problem and ask questions about the solution of the problem. She simulates a geometrical rule to encourage students to notice the relationship between geometrical parameters. The problem was; “How can you create a single triangle which has the same area with the polygon given below? Provide your reasoning.” The problem of the lesson presented in Figure 2.

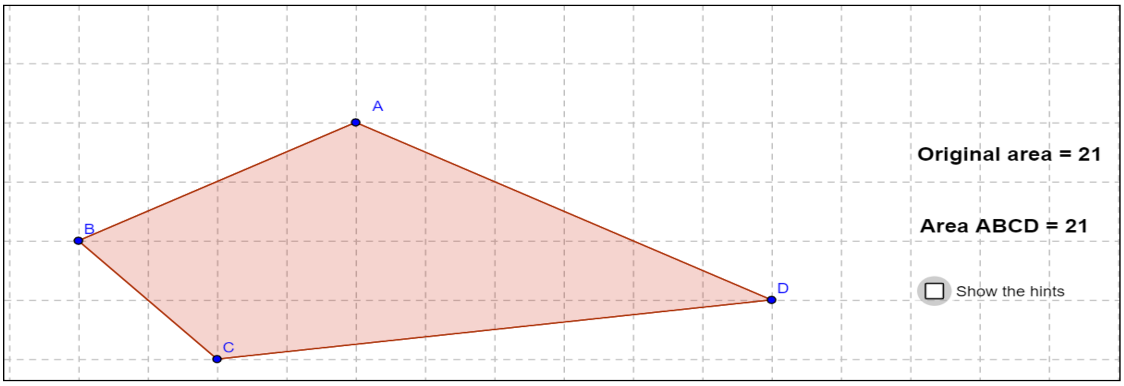


Figure 2. Meltem’s First GeoGebra Problem (Source: Authors’ own illustration)

The technology based activity includes structured inquiry tasks towards intended ideas. Technology procedures concentrate on mathematical task and helps students to make connections, so it can be said Meltem’s performance for the C1 (purpose) was consistent with the adapting level.

In the lesson, Meltem asked: *“we have a quadrilateral and it has four vertex, we want to make it triangle, so what can we do?* Then she let students discuss the solution of the problem. Meltem asked students how could they omit the vertex and wanted them to explain their conjectures. Then to display students carrying one of the vertex points on to the extension of the other side, she clicked on the checkbox in the GeoGebra file named “Show the hints” and moved the slider step 1 to step 4 as stated in Figure 3.

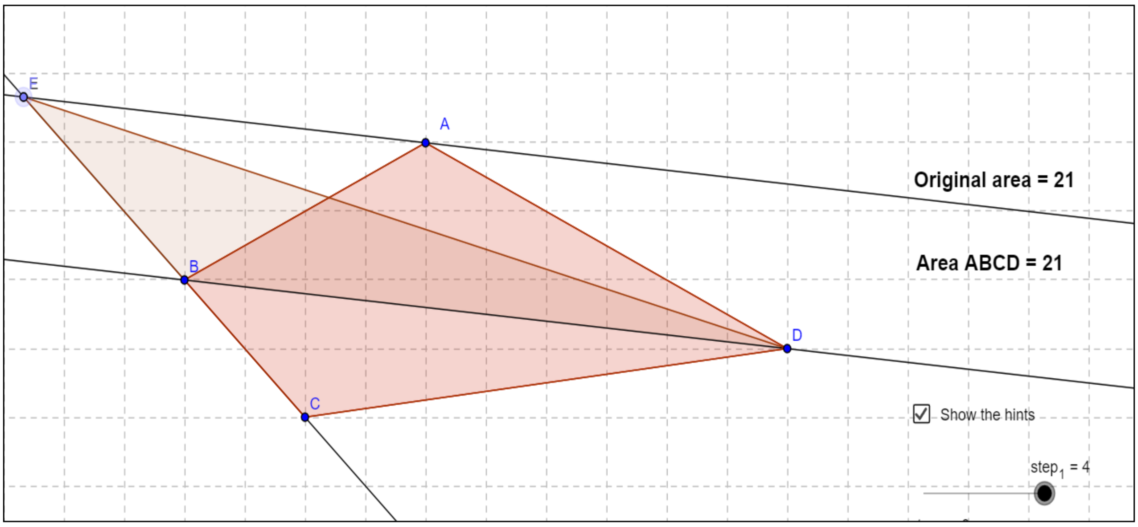


Figure 3. Showed the hints (Source: Authors’ own illustration)

In the GeoGebra activity she had one of the dynamic vertex points of the quadrilateral moved, in this way students had a chance to observe changes in the area of triangle and quadrilateral dynamically and observed that the area of the triangle is the same in both cases. Meltem’s performance for the C2 (students’ understandings) was consistent with the accepting level. At an accepting level digital materials for students mirror the structure of the traditional textbook presentation of mathematics (Lyublinskaya & Kaplon-Schilis, 2022).

In the lesson students only observed the activity without active dynamic exploration. GeoGebra task was planned to explicitly promote student knowledge by posing of questions for sense making as;

Meltem: What will happen if I carry point A to E. Let me check

Student : I think we need to carry point A to point E.

Meltem: GeoGebra has drew a line on the BC side of the polygon. Why do you think we need this line?

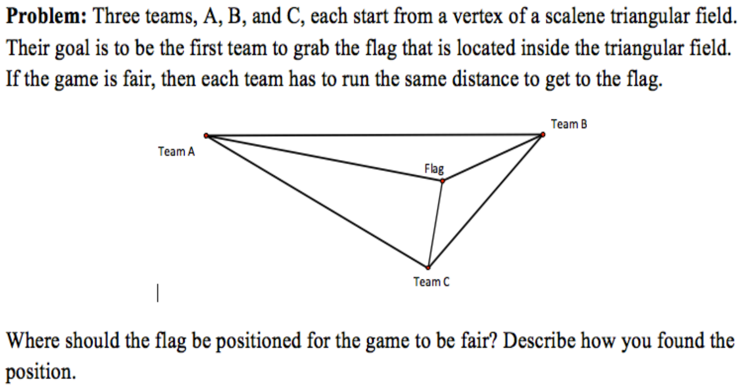
She asked for only volunteer students to give one more try with GeoGebra and a students tried to fix them up. Meltem asked questions to have student think about the two triangles and share their opinions. Then she showed the students' the measurements of areas were equal via dynamic text boxes in GeoGebra file. Finally the correct reasoning was identified by the Meltem, which was "we have drawn a parallel line to BD passing through point A. Students were interested in the lesson, however, they couldn't actively engage in discussion. Larger part of the class time technology could be used by students who explore and experiment with it for new knowledge, however, Meltem didn't give this opportunity to the students. The questions that she asked were so high level that most of the students couldn't answer. In this lesson, the applet used by the teacher provided students with answers like a textbook material, so that supports it was an accepting level.

Meltem's performance for the C3 (curriculum) was consistent with the adapting level. Students are not given opportunity to explore with technology, it was a teacher's demonstration and very structured. This task replaced non-technology-based presentation with technology-based demonsration (using sliders to get from one picture to another one). With this activity, Meltem provided "hint" that showed parallel lines and slider, the task leads to basic understanding of the topic, it does not lead studenst to expand math ideas based on their own explorations.

Meltem's performance for the C4 (strategies) was consistent with the adapting level. In general Meltem uses a deductive approach to teach and to maintain control of the progression of the exploration activities. In the first lesson, Meltem controlled the activity witout students participation of the class discussions. She didn't give enough wait time for the students to explore and discover the mathematical relationships. In the lesson, 8 of 29 students got the chance to use the educational technology to explore. At the end of the reaction in action process (interview) Meltem talked about difficulties while finding time to ask challenging questions and giving enough wait-time to students because of the time limitation. For the next lesson she planned to give longer wait time to the students and opportunitiy to explore their opinions via GeoGebra.

Second Lesson Implementation

At the second lesson, Meltem used GeoGebra to model real-life problem. The problem in the lesson was stated in Figure 4.



Problem: Three teams, A, B, and C, each start from a vertex of a scalene triangular field. Their goal is to be the first team to grab the flag that is located inside the triangular field. If the game is fair, then each team has to run the same distance to get to the flag.

Where should the flag be positioned for the game to be fair? Describe how you found the position.

*Figure 4***.** Problem of the Second Lesson (Source: Authors' own illustration)

The purpose was to have students experience mathematical discoveries via GeoGebra. Meltem modeled a problem and prepared hints for students to assist them in the solution process. She constructed two trial activity via GeoGebra to have students explore and make conjecture about the geometry concepts. There were three teams whose goal was to be the first team to grab a flag located inside the triangular field. Their starting points were the three vertexes of the triangle. Meltem aimed to give students more opportunity to explore mathematical concepts via GeoGebra by their own computer and pace. She implemented her second lesson in the computer lab. In the file, she generated a trial file for students to observe and make conjecture about the exact place for circumcenter of an acute triangle. In this part she gave hints for the students by using checkbox named "hints." She designed a single slider with six intervals. Each point on the slider corresponded to a new step in the problem. She had created hints linking lines to slider step by step. During the lesson, students solved the problem by using these hints. Students click on the file and opened the file and she asked students to click on the checkbox named "deneme" means "trial" and try to place point D to make three lengths of AD, BD and CD were equal as presented in Figure 5.

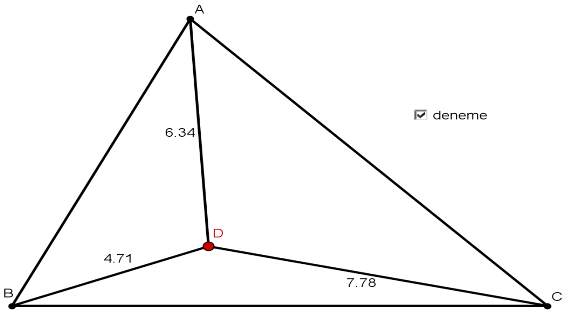


Figure 5. Meltem's Trial (Deneme) Activity (Source: Authors' own illustration)

The aim of the trial GeoGebra activity was having the students explore and predict the exact place for the flag. The problem required students to find the circumcenter of the triangle. Her goal was to have students create an experiment and discover how to find the circumcenter of a triangle. This trial activity enabled the students to find the location of the circumcenter of a triangle. However, Meltem created GeoGebra file for students that provided them with the path to solution, it was still a structured inquiry. One of the students said;

Student: As if there is a circle passing through vertexes of triangle and we are looking for center of this circle.

Meltem: Yes you are right, do you have any idea about how to find center point of this circle?

Student: Yes, look at this I almost found the point the length of the distances very similar.

Meltem: Why this point is about there. You can find with the help of GeoGebra where the point is. You need to give an explanation.

Meltem's performance for the C1 (purposes) was consistent with the adapting level again. Meltem showed students that it is a circumcenter through a structured activity, so this technology based activity would be an adapting level. The main difeference from previous lesson was students spent more time with technology individually to go through problem solution. GeoGebra provided an environment for students to take mathematically meaningful actions on circumcenter of a triangle. However solution is given to the students by Meltem as explained above. Step by step students would move the slider and go through the solution of the problem.

Meltem's performance for the C2 (students' understandings) was consistent with the adapting level. Meltem's goal was modeling a problem task where students could practice different ways of reasoning and confirm their opinions about the solutions of the problem via measuring lengths, dragging, tracing, and drawing lines. When she had difficulties getting students to answer the questions, they were prompted through hints and able to answer all questions by the end of the activity. The students were presented with question-rich situations that they could explore via GeoGebra under a variety of conditions and modeling assumptions. Meltem's planned role was directing students through the solution by ordering the timing and sequence of questions.

Meltem: Let's look at the board. To solve the problem, I want to ignore one of the vertex points, for example vertex point "A." Now I changed the problem let's find me a point that equidistance from vertex B and vertex C.

She said. There was no answer. Then she drawn an imaginary triangle with her forefinger on to the board and asked;

Meltem: What kind of triangle it might be.

Students said isosceles triangle chorally. Meltem confirmed students' answer and asked them move the slider to Step 1. Meltem and students moved the slider to Step 1 and saw GeoGebra window presented in Figure 6.

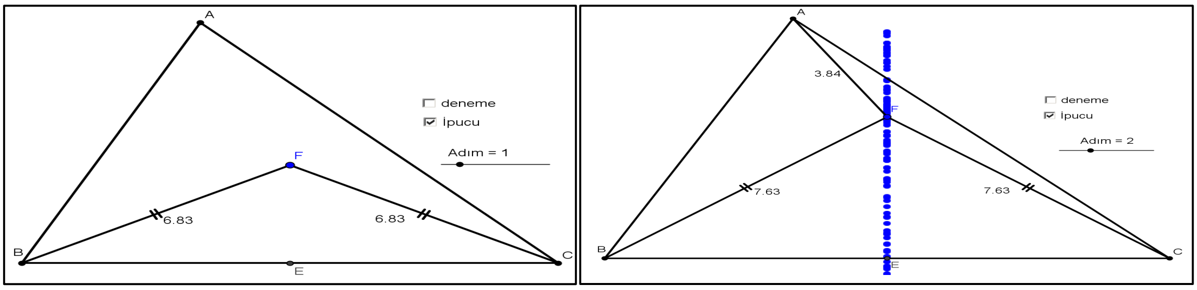


Figure 6. First and second step of second problem in second lesson (Source: Authors' own illustration)

With the help of an isosceles triangle with a dynamic top point, students noticed that this point was always equidistant from each vertex. When students move the slider one step further, AF segment was appeared as presented in Figure 6.

Meltem: Look at the point, is it ok now? Did we found the point that we are looking for?
Student: No it is not. The length of the AF is not equal the other two.

Then she asked students what else, they need to make the length of AF equal to IBFI and ICFI. After that she gave five minutes to the students to come up with their own strategies. Then she suggested students move point F, and interpret the right place.

Student: The point should be on the perpendicular bisector. Actually, I almost found the exact place for the point, the lengths are 6.3, 6.3 and 6.33.
Meltem: yes you are right the point should be on the perpendicular bisector. Think about it.

At that time one of the students found the exact point via GeoGebra and showed to the class mates around her as presented Figure 7.

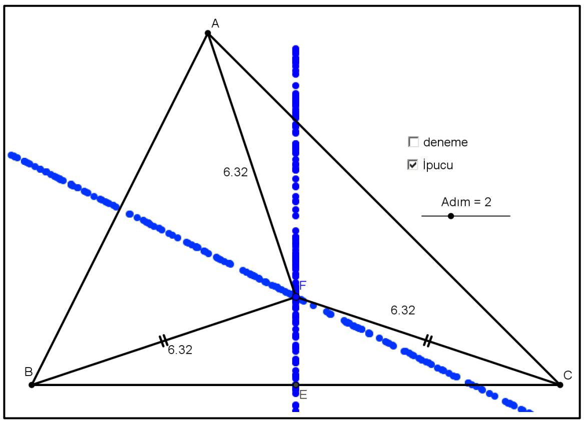


Figure 7. Point found by student (Source: Authors' own illustration)

The intersect point of perpendicular bisector of AB and BC was the point that they were looking for. Meltem wanted students to display it via GeoGebra.

At the second implementation Meltem's performance for the C3 (curriculum) was consistent with the adapting level. In this lesson, Meltem was a guide for students to noticed students the logic behind the constructing a circumcenter of a triangle. Meltem found the intersection point of perpendicular bisectors, this point is circumcenter of this triangle.

Students realized that point H is circumcenter of the triangle ABC. Then Meltem asked students to move the slider Step 6.

Meltem asked students to check the equivalence of three lengths, AH, BH and CH via GeoGebra. Students chose "distance or length" from the menu and measure the three lengths. Students saw that three of the lengths were equal. Therefore, students concluded that for a fair competition the flag should be placed at point H. The student, who recognized that this point was center point of circumscribed circle repeated his idea and showed with his finger a circle with center point H and pass through points A, B and C.

Meltem: Could you check your idea via GeoGebra.

Student: Yes

After that Meltem chose a “circle” from GeoGebra menu and draw a circle pass through point “A” with a “H” center point as presented in Figure 8.

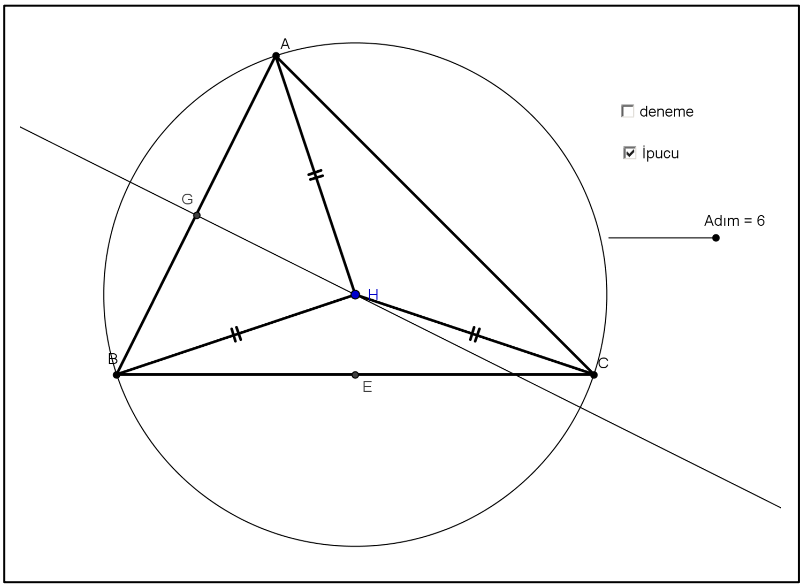


Figure 8. Circumcircle of the triangle (Source: Authors’ own illustration)

Then, Meltem asked students to write the solution of the problem on their activity sheet in detail. GeoGebra used by students in the larger part of the class time in order to explore and experiment with it for new knowledge and practice. Students saw the point they were looking for, which was intersect point of perpendicular lines from each side. Because the teacher provided “hint” that showed parallel lines and slider, the task leads to basic understanding of the topic, it does not lead studenst to expand math ideas based on their own explorations. The task as described also does not support student in developing new mathematics ideas. This was an adapting level.

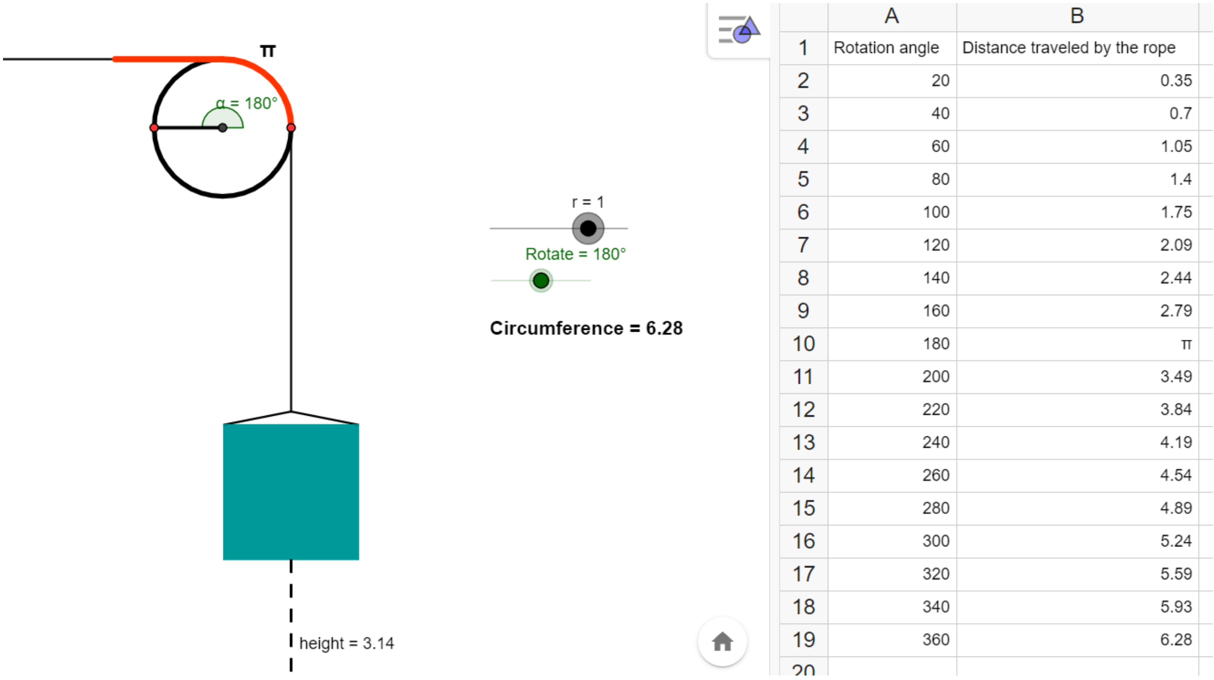
At the second implementation Meltem’s performance for the C4 (strategies) was also consistent with the adapting level. C4 mainly related to the knowledge of instructional strategies and representations for teaching and learning mathematics via technology. At this level teacher uses a deductive approach to teaching with instructional technology. Digital materials are built around mathematical objects but do not promote student reflection. In the lesson, Meltem prepared a dynamic environment for students to explore the location of the circumcenter of a triangle. She observed students’ examinations in the groups and gave feedback to them. She assisted students via hints when they need in solution process of the problem. She promoted student reasoning by posing of questions for sense making about the relationship between geometrical concepts. She tried to engage students into the class discussions. After discussing each step, students went on to the next step to find the circumcenter of triangle. Trial files provided a dynamic environment for students to explore the location of the circumcenter of a triangle. The questions were appropriate for the students’ level, meaning that 14 of 23 students could answer. At the end of the reaction in action process (interview) Meltem stated that during the lesson, students had a chance to explain their strategies, and conjectures by giving evidences and test their own mathematical ideas with the help of GeoGebra to find out the right place of circumcenter of a triangle. She said that it was more difficult than she thought to have students completed the task.

Third Lesson Implementation

Meltem constructed a simulation of transportation system to pull a box up via GeoGebra. In the simulation, there was a pulley rotated by angle controlled by a slider. When the pulley was rotated by angle via slider the box was lifted constructed a GeoGebra file to model a problem. The teaching method that Meltem planned to use was problem solving. In the GeoGebra activity she simulated a transportation system problem. When a pulley was rotated by an angle, controlled by the slider, the box was lifted. Meltem’s performance for the C1 (purposes of integrating technology) was consistent with the exploring level. *At this level teacher plans for instructional technology to be used mostly by students who explore and experiment with technology for subject matter development* as stated in Lyublinskaya & Kaplon-Schilis, (2022).

Technology procedures focused on doing mathematics while using or making connections (Lyublinskaya & Kaplon-Schilis, 2022). The aim of the this activity was to have students observed and noticed the relationship between angle of rotation and distance traveled by starting point of the box. With the help of this file students observed when the pulley is 360° rotated, box is lifted 2πr units up and they concluded in the discussion that when the pulley is rotated by α degrees, the rope is pulled $\frac{\alpha}{360°}x2\pi r$ units up. The common purpose of these activities was using educational technology to have students observed the relationship between geometrical concepts and make interpretation about these relationships. Meltem's level for the C1 increased from adapting level to exploring level. In order to interpret this equation to students, Meltem provided spreadsheet view of these parameters via GeoGebra. In spreadsheet view there were two columns for the angle of rotation and distance traveled by starting point corresponding to that rotation angle together. Visualization of the pulley related to central angle and arc of it was helpful for students to get the logic behind the pulley system.

The problem was stated in Figure 9.



	A	B
1	Rotation angle	Distance traveled by the rope
2	20	0.35
3	40	0.7
4	60	1.05
5	80	1.4
6	100	1.75
7	120	2.09
8	140	2.44
9	160	2.79
10	180	π
11	200	3.49
12	220	3.84
13	240	4.19
14	260	4.54
15	280	4.89
16	300	5.24
17	320	5.59
18	340	5.93
19	360	6.28
20		

Figure 9. Meltem's Third Lesson: Angle of Rotation and Distance Traveled by Starting Point (Source: Authors' own illustration)

To begin with, she asked students to observe what was happening when the pulley was rotated by angle controlled by the slider. She wanted to have students make comments about the arc which was the distance traveled by the starting point on the rope when the pulley was rotated. To visualize the arc she had colored it red and moved the system via slider for students to observe.

Meltem: Do you have any idea about how much is the box lifted when the pulley is rotated.
Student: There is a relationship between arc and height.
Meltem: Well, how many centimeters box goes up when the pulley is rotated by 360°?
She rotated the pulley 360° via GeoGebra.

Student: Circumference of the pulley.

Meltem: Well, If I rotate the pulley 180°?
Student: Then it goes up half of the circumference of the pulley.

At the third implementation Meltem's performance for the C2 (knowledge of students' understandings, thinking, and learning) was exploring level. The exploring level is how technology is used by students – it was guided inquiry explorations, not a structured task as previous two lesson implementation. To guide students in solution process, Meltem constructed six steps hints via GeoGebra. The aim of the hints was to encourage students to answer the questions. Without educational technology it would be more difficult to display relationships between geometrical concepts in a dynamic way and challenge students via hints. At exploring level *teacher facilitates students' use of instructional technology to develop thinking leading to a conceptual understanding of mathematics* as stated in Lyublinskaya & Kaplon-Schilis, (2022). In the lesson, Meltem facilitated students' thinking with technology-linked representations. She constructed concrete materials via GeoGebra to visualize the mathematical concepts and simulate the relationship and give students hints about the solution of the problem.

Students were challenged to find an equation between angle of rotation and distance traveled by starting point. Meltem encouraged students to share their ideas about their observation. She helped students verbalize their ideas asking several questions and making restatements. Her focus was challenge students cognitively for conceptual understanding. She gave hints to students step-by-step and tried to force the rest of the students who observed the activity and didn't answer the inquiry questions. The questions that she asked were not high level for students that students could answer. Instead of observing teacher demonstrations, students actually did mathematics in the third lesson. Via GeoGebra students could move the objects within the model and observe patterns of parameters that emerge as a result of moving it. This helped them to notice relationship between these parameters. In addition, students had a chance to see the spreadsheet view of these parameters. In spreadsheet view there were two columns first one was the angle of rotation and the second one was distance traveled by starting point corresponding to that rotation angle together. Students could interpret the proportionality and explained this model by writing an equation. Meltem used GeoGebra to have students observed the relationship between these geometrical concepts and challenged to find an equation between angle of rotation and distance traveled by starting point.

Meltem used educational technology to have students make judgments about the geometrical rules. The activity she construct offered opportunities for "math talk" to take place between students and students, and students and teacher. Some of the students could explore the relationship between geometrical concepts and test their conjectures. Meltem used technology in a constructive way, including tasks for deepening understanding of mathematics concepts. Students were challenged to find an equation between angle of rotation and distance traveled by starting point. This helped students to notice relationship between these parameters. Students could interpret the proportionality and explained this model by writing an equation. Students are given curriculum-based tasks with technology and are asked to expand mathematics ideas on the basis of technology explorations.

Meltem's performance for the C4 (strategies) was consistent with the exploring level. The role of the Meltem was a guide to promote students' reflections and making sense with mathematical concepts via GeoGebra. Meltem used technology to modeled a problem via GeoGebra and asked questions to students throughout the lessons she made students wonder about the problem to solve it via giving hints. She explicitly promoted student reflection especially the posing of questions for sense making. Meltem could check the students' suggestions via GeoGebra. She tried not to answer her questions; asked different versions of the same question and gave some examples to have students find the correct answer. As stated she at the interview the only problem in the planning of instruction was time limitation.

These three lesson implementations demonstrated that Meltem possesses the requisite technological, pedagogical, and content knowledge to develop technology-based activities and execute them effectively within an elementary school setting. She wrote her last reflection paper that "I had the chance to prepare my own lessons and teach the same class for five [2-2-1] hours. Those experiences encouraged me a lot to trust my activities and be more hopeful about my future teaching. I tried to focus on my mistakes in each class and tried to eliminate them in the next one. I can say that this was the most educative experiences for me." Meltem's performance in these three lesson implementations represented in the Figure 10.

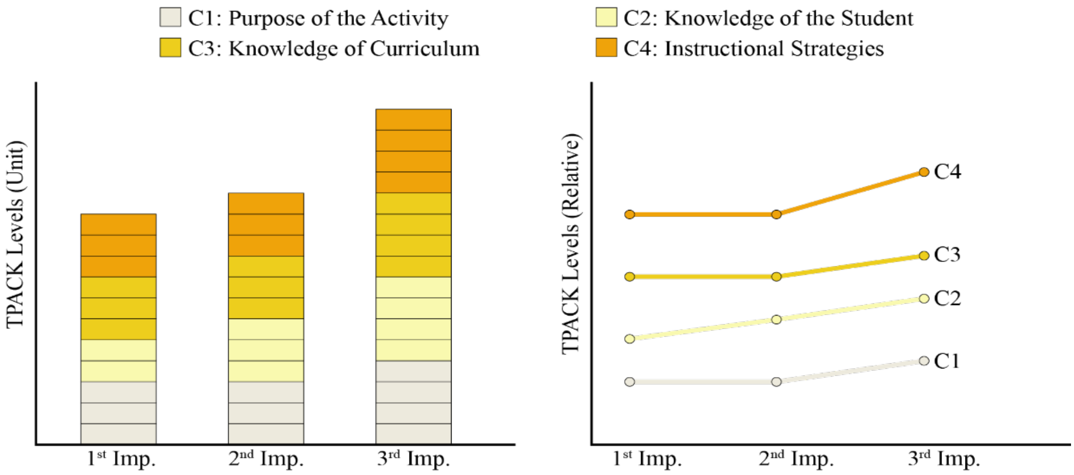


Figure 10. Meltem's TPACK Levels (Source: Authors' own illustration)

DISCUSSION CONCLUSION and SUGGESTION

Studies claimed that PMTs advanced their TPACK after having experience with technology-based teaching practices (Kaplon-Schilis, & Lyublinskaya, 2016; Mouza & Karchmer-Klein, 2013; Oner, 2020; Papanikolaou et al., 2022; Stapf & Martin, 2019). Mouza & Karchmer-Klein, (2013) indicated that designing, enacting, and reflecting on technology-integrated classroom experiences enables PMTs to recognize connections between technology, content, and pedagogy and to advance their TPACK. Niess (2008) stated that this practice requires PMTs to notice when, where, and how technology enhanced their teaching. Reporting on their own efforts strengthens their teaching via technology. In a related study, Hixon and So (2009) emphasized the importance of technology-based lesson implementations in fostering the development of PMTs' TPACK. Throughout these teaching activities, PMTs evaluated the suitability of their lesson designs for classroom use and identified fundamental prerequisites for teaching mathematics with technology (Hixon & So, 2009; Zeincher, 2010). According to results of the study four main components of the lesson the purposes of incorporating technology in teaching, the inquiry questions used, and the instructional strategies determined the change in the TPACK level of the PMTs. There was no significant change in PMTs' knowledge of curriculum from first implementation to the end.

The first theme was a change in the purposes of incorporating technology in teaching. As PMT gained experience in classroom contexts, the aim of the technology-based activity was changed. For example, in the first lesson, Meltem used GeoGebra to demonstrate a dynamic model for a problem and gave students hints about how to solve the problem. Even if, this technology-based activity assisted Meltem in helping her students work out the solution to the problem, limited number of students reached this opportunity. After the reflection-in-action process, Meltem reliazed that she needs to give more opportunity for all students and decided to implement her second lesson in the computer lab. In the second lesson, Meltem used GeoGebra to model real-life problem. This time, she constructed two trial activities with the aim of having the students work alone to explore and predict the solution of the problem by their own pace. First and second lesson there was a structured task prepared by the PMT, at the third implementation the use of technology by students was for exploring. In the third lesson, the activity included interdisciplinary arguments related to physics and the students had the opportunity to make connection between science and math. The instructional method was guided inquiry explorations. In a similar study, Mudzimiri (2012) also found that participants initially believed that technology is used for drill-and-practice. Through designing and implementing a second group lesson, they appeared to have progressed in their TPACK.

The second theme was a change in the type of questions asked by Meltem. For example, in the first lesson the questions that Meltem asked gave hints to enable students to notice the solution to the problem. Using hints, Meltem had tried to engage students in the solution process. However, the questions were so difficult that very few of the students were able to answer. In addition, she did not wait long enough for the students to explain their opinions. In the second lesson, Meltem adopted a more constructivist form of pedagogy and gave her students the chance to experience mathematical discoveries using the GeoGebra. She allowed students to present, pose their ideas, interpret, compare, and reflect on the solution to the problem.

She made more effort to engage the students in class discussions by asking reasonable questions. In the third lesson, as with the second lesson, Meltem continued to display a more constructivist form of pedagogy. Meltem gave enough time for her students and to explain their answers in the second and third implementations as compared with the first implementation. Zbiek (2003) emphasized the importance of classroom discussions to facilitate the emergence of mathematical ideas through rationalizing mathematical concepts in technology-based lessons.

The third theme was a change in the role of the teacher. As the PMT gained classroom experience, the previously discussed changes to the activities' aim and the questions in the lessons altered the PMT' role in the lesson. For example, Meltem held the role of lecturer in the first lesson. She took a direct instruction approach, using technology to assist in her teaching. Technology was rarely used by the students, because the design of the lesson did not support students' independent use of technology for exploration. In the second lesson, Meltem prepared a dynamic environment for students to explore the process of finding the circumcenter of a triangle. She observed students in small groups and gave feedback. She promoted student reasoning by posing questions that got them to make sense of the relationships between geometric concepts. Meltem served as a guide for students, who were learning by using technology in the computer lab. In the third lesson, Meltem again used educational technology to have her students make judgments about geometrical rules. In this lesson Meltem's role was that of guide, to promote student reflections and make sense of mathematical concepts using GeoGebra. In a parallel study, Valanides and Angeli, (2008) also found that as teachers implement more technology-based lessons, their confidence in integrating technology into their lessons in student-centered ways increases.

This study has asserted that technology-based lesson implementations, combined with the reflection-on-action process, could have contributed to a shift in PMT's TPACK levels over the course of three lesson implementations. The participant initially focused on how to use the technology, but showed progress in terms of focusing more on mathematics in order to have students explore concepts using educational technology (Mudziri, 2012). By implementing technology-based lessons, PMT's get the chance to see concrete examples of how dynamic geometry software can be used effectively in a mathematics classroom.

This study showed that when teacher candidate has teaching experience in technology-based real classroom environments, her purpose in using educational technology changes incrementally. In the first lesson, participant did not offered much opportunity for students to investigate mathematical ideas using educational technology. By the second lesson they conducted more student-centered lessons and paid great attention to integrating students into the lesson via reasoning questions using educational technology. Then in the last lesson they progressed further and they taught with educational technology using different examples (Balgalmis, 2013). The critical explanation is that the TPACK of teacher candidates develops more with their own experiences, even if they are taught different examples of how to use technology in their coursework (Balgalmis et al., 2015; Hixon & So, 2009; Mouza & Wong, 2009; Mudzimiri, 2012; Valanides & Angeli, 2008). Having theoretical knowledge, developing technical ability, and getting high scores from technology-based lessons does not guarantee ease in implementing a technology-based lesson in a real classroom environment.

The findings of the current study have revealed some implications that needed to be taken into consideration by teachers, teacher educators and the researchers who deal with TPACK studies. The present study underlines the teaching practice course supported with reflection-on-practice processes in order to enhance PMT's TPACK for teaching mathematics. This study claimed that technology-based lesson implementations coupled with reflection-on-practice helped support PMT's TPACK development in teaching practice course. Discussing the lesson implementation helped them notice their strengths and weaknesses and work on the weaknesses for the next lesson. As the number of practice lessons increased, so the observed evidence concerning the change in PMT's' TPACK increased. At least three technology-based lesson implementations are suggested to determine the PMT's TPACK level. This process might give clues to teacher educators about how to design teaching practice courses that will help PMT deal with technology-based teaching activities. In this process university facilitators and mentor teachers played an important role in helping PMT to bridge theory and practice. Ideally, university facilitator assist PMT in the reflection-on-action process and mentor teachers should have been a role model for PMT when carrying out technology-based lessons.

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