

AN INVESTIGATION OF PRE-SERVICE ELEMENTARY MATHEMATICS  
TEACHERS' TECHNO-PEDAGOGICAL CONTENT KNOWLEDGE WITHIN THE  
CONTEXT OF THEIR TEACHING PRACTICES

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Approval of the Graduate School of Social Sciences

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## **ABSTRACT**

### **AN INVESTIGATION OF PRE-SERVICE ELEMENTARY MATHEMATICS TEACHERS' TECHNO-PEDAGOGICAL CONTENT KNOWLEDGE WITHIN THE CONTEXT OF THEIR TEACHING PRACTICES**

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The goal of the case study was to investigate the contribution of field experience and the reflection-on-practice process on Turkish Pre-service Teachers' TPACK. In 2011-2012 fall semester, the research was conducted with the participation of three PSTs. PSTs designed and implemented three technology-based lessons, primarily with GeoGebra. They were observed during the lesson and interviewed before and after each lesson implementation to reflect on their teaching. The data collection methods were reflective interviews, observations, videotaped lessons and documentation. The data were analyzed through qualitative data analysis methods. A five level TPACK rubric (recognizing, accepting, adapting, exploring and advancing) was used.

The qualitative analysis of the data revealed that PSTs TPACK levels changed progressively throughout the study. Three components; the aim of the lesson, the questions used, and the role of the teacher provided important insights to determine the change in the TPACK level. PSTs' interpretations of implementing technology-based mathematics lessons were examined. The thirteen themes emerged in the interviews

were classified into three categories. The categories and their themes were the lesson preparation (students' pre-knowledge, lesson objective, location, necessity of the technology, motivation), process of implementation (tool, teacher role, activity sheet, classroom management, time management, implementation), and mentorship (having a facilitator, and recommendation). In general PSTs defined educational technology as a tool that assisted them to promote students' learning and increase students' motivation. Findings support the need for teaching experience and reflection-on-action, to promote PSTs' TPACK. These were the important components, which affected the overall success of their lesson implementation.

Keywords: Pre-service Mathematics Teacher Education, Technology Integration, GeoGebra, Techno-Pedagogical Content Knowledge, Field Experience

## ÖZ

### İLKÖĞRETİM MATEMATİK ÖĞRETMEN ADAYLARININ TEKNO-PEDAGOJİK ALAN BİLGİLERİNİN ÖĞRETİM DENEYİMLERİ BAĞLAMINDA İNCELENMESİ

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Bir örnek olay incelemesi olan bu çalışmanın amacı, teknoloji destekli öğretim deneyimi ve yansıtıcı düşünme süreçlerinin, Türk Öğretmen Adaylarının TPAB'lerine olan katkılarını araştırmaktır. Çalışma 2011-2012 güz döneminde, üç ilköğretim matematik öğretmen adayının katılımıyla gerçekleştirilmiştir. Öğretmen adayları öncelikli olarak GeoGebra dinamik geometri programını kullanarak, teknoloji-destekli üç matematik dersi planlayıp, uygulamışlardır. Öğretmen adayları, bu uygulamalar sırasında araştırmacı tarafından gözlenmiş ve her bir ders uygulamasının öncesi ve sonrasında uyguladıkları derse yönelik yansıtıcı görüşleri alınmıştır. Araştırmada yansıtıcı görüşmeler, gözlemler, ders kayıtları ve dökümanlar veri toplama araçları olarak kullanılmıştır. Veriler, nitel veri analizi teknikleri ile analiz edilmiştir. Araştırmada, beş aşamalı TPAB değerlendirme rubriği (farketmek, kabul etmek, uyarlamak, keşfetmek ve ilerlemek) kullanılmıştır.

Nitel veri analizi sonuçları, öğretmen adaylarının, çalışma süresince TPAB düzeylerinde, artan bir değişim olduğunu göstermiştir. Dersin üç özelliği, dersin amacı, soruların niteliği ve öğretmen adayının derste rolü TPAB düzeylerindeki değişimi



belirleyen önemli ipuçları sağlamıştır. Çalışma kapsamında, öğretmen adaylarının, teknoloji-destekli matematik eğitimi uygulamalarına yönelik görüşleri de araştırılmıştır. Görüşmelerin analizinden çıkan on üç tema, üç kategoride sınıflandırılmıştır. Kategoriler ve temaları; derse hazırlık (öğrencilerin on bilgileri, dersin kazanımı, ders ortamı, teknoloji kullanımının gerekliliği, motivasyon), dersi uygulama süreci (araç, öğretmenin rolü, çalışma kâğıdı, sınıf yönetimi, zaman yönetimi, uygulama), ve mentorluk (kolaylaştırıcının olması ve tavsiyeler) olarak belirlenmiştir. Öğretmen adayları, eğitim teknolojilerini genel olarak, öğrencilerin öğrenmesini geliştirmek ve onların derse olan motivasyonunu artırmak için kullandıkları kendilerine yardımcı bir araç olarak tanımlamışlardır. Sonuçlar teknoloji destekli öğretim deneyimi ve yansıtıcı düşünme süreçlerinin, öğretmen adaylarının TPAB düzeylerinin geliştirilmesi için gerekli olduğunu göstermiştir. Bunlar teknoloji destekli matematik dersi uygulamalarının genel başarısını etkileyen önemli özelliklerdir.

Anahtar Kelimeler: Matematik Öğretmen Eğitimi, Teknoloji Entegrasyonu, GeoGebra, Tekno-Pedagojik Alan Bilgisi, Öğretmenlik Uygulaması

This dissertation is dedicated  
to

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for their endless love

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## **LIST OF ABBREVIATIONS**

|       |                                                                                        |
|-------|----------------------------------------------------------------------------------------|
| CK    | Content Knowledge                                                                      |
| ELE   | Elementary Education                                                                   |
| EME   | Elementary Mathematics Education                                                       |
| PCK   | Pedagogical Content Knowledge                                                          |
| PSTs  | Pre-service Elementary Mathematics Teachers                                            |
| TPACK | Techno-Pedagogical Content Knowledge or Technological<br>Pedagogical Content Knowledge |

## **CHAPTER I**

### **INRODUCTION**

For the last twenty-five years, technological tools have become commonplace in many aspects of professional and personal lives of individuals. Despite widespread usage of technology across many disciplines in 21st century, it is rarely used in education. Rapid changes and remarkable advances in technology forced to drive educational institutions to adapt technology into their activities (Campbell, Peck, Horn & Leigh, 1987; Gülbahar, 2008). Before 1983, there was almost no literature about using electronic technologies in the educational environment (Kaput & Thompson, 1994).

In recent years, technological tools such as graphing calculators, electronic white boards, spreadsheets, applets, interactive online learning systems, simulations, web pages and dynamic geometry software have been emerging in educational studies to improve the teaching and learning environment (Kim & Baylor, 2008). According to the National Council of Teachers of Mathematics (NCTM, 2000) technology is essential and necessary in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning. By appropriate use of technology in mathematics classroom, students learn mathematics conceptually is commonly accepted (Stohl, 2001; McCoy, 1996; NCTM, 2000).

The current elementary mathematics curriculum developed by Ministry of National Education (MONE) in Turkey emphasizes using technology effectively in teaching and learning process to provide students the opportunity for expressive mathematics teaching (MONE, 2013). For instance, with the help of dynamic geometry software, students construct geometric shapes and make connections between them. Additionally, dynamic geometry activities prepared by teachers provide students the



opportunity to interact with and investigate the content with their peers (MONE, 2013). The “Subject Matter Competencies for Teachers” written by the current General Directorate of Teacher Training (ÖYGM), addressed the need for technologically literate teacher in order to plan and regulate teaching activities (ÖYGM, 2010). In addition to having subject matter knowledge, pedagogical content knowledge, and skills of implementing the curriculum based on this knowledge, teachers need to know how to use effectively technology in their teaching activities.

In order to provide educational technology facilities to teachers and learners, Ministry of Turkish Education established Directorate General for Innovation and Educational Technology (YEĞİTEK) in 1998 (YEĞİTEK, 2010). YEĞİTEK prepares learning environments for efficient technological applications and develop projects such as FATİH, Intel Teacher, Intel Students to encourage the use of technology for teaching and learning activities. Intel Teacher Program is an international program aims to embrace all school subjects and all current developments in educational technology. This program compensates the need for technologically literate teacher who can use new technologies effectively to enhance students’ learning by in-service training.

According to National Council for Accreditation of Teacher Education Standards (2002), in the USA, the new professional teacher who graduates from a department of education should be able to integrate technology into instruction to effectively enhance student learning. To achieve the technological goals, teachers have to be prepared for their new roles in a technological environment (Thompson & Kersaint, 2002). To design and structure learning environments, researchers have suggested that teacher educators need to integrate technology into their teaching (Thompson & Kersaint, 2002) and their technology integration should go well beyond teaching technical skills (Kim & Baylor, 2008). Therefore, many teacher training programs and professional development initiatives integrate technology, with educational aims, into the courses to develop pre-service teachers’ knowledge of technology (Katic, 2008; Koehler & Mishra, 2005). Turkish General Directorate of Teacher Training and Education (ÖYGM) declared

educational technology as a required competency for mathematics teachers to be a qualified mathematics teacher in 2008. According to their standards professional mathematics teacher should become aware of the importance of the using educational technology in teaching for effective learning. Teachers should have the technical skills to use subject specific educational technologies and use this knowledge in teaching actively. In addition, teachers should share their technical knowledge and experiences with their colleagues (ÖYGM, 2008). As technology plays an ever-increasing role in the lives of elementary school students, dynamic technology-supported instruction presents an opportunity to enhance mathematical reasoning and explore various conjectures of pre-service elementary teachers. Graphing calculators and dynamic software packages - such as GeoGebra, Geometer's Sketchpad, and Tinkerplots are vital in raising student awareness, challenging their conceptual understanding and motivating the synthesis of mathematical notions (Hollebrands, 2007; Kaput & Thompson, 1994; Peressini & Knuth, 2005). Construction of mathematical objects, creating models and conducting interactive explorations are available via GeoGebra by dragging objects tracing points, changing parameters and measuring objects. Pre-service teachers should be challenged to reorganize their subject matter content and how to use educational technology on the development of that subject itself as well as on teaching and learning that subject (Niess, 2005). In order to be an effective teacher, pre-service teachers need to know fundamental concepts, knowledge, skills, and attitudes for applying technology in educational settings (NETS•T, 2008, p.1). This perspective suggests that teacher preparation programs must provide numerous experiences to engage the pre-service teacher in investigating, thinking, planning, practicing, and reflecting (Niess, 2005).

### **1.1 Statement of the Purpose and Research Questions**

The two main goals of this study were to explain the change in three PSTs' progress in the usage of techno-pedagogical knowledge during their field experiences

and identify PST's interpretations after designing and implementing three technology-based lessons about this experience. With this aim, the central research question guiding the study was the following questions:

1. What are PSTs TPACK levels in three different teaching implementations?
2. To what extent do PSTs develop their TPACK through the implementation of three technology-based lessons in a field experience?
3. How do PSTs interpret their experiences with educational technology through the implementation of three technology-based lessons in a field experience?

## **1.2 Significance of the Study**

In recent years, a number of studies have been conducted to present effectiveness of educational technology in teaching. Teacher training programs should provide PSTs a rich technological environment to develop techno-pedagogical knowledge and skills (ÖYGM, 2010). According to the National Council for Accreditation of Teacher Education standards (NCATE, 2002), the new professional teacher who graduates from a department of education should be able to integrate technology into instruction to effectively enhance student learning. To achieve the technological goals stated by NCATE, teachers have to be prepared for their new roles in a technological environment (Thompson & Kersaint, 2002). To design and structure learning environments, researchers have suggested that teacher educators need to integrate technology into their teaching and their technology integration should go well beyond teaching technical skills (Kim & Baylor, 2008). Therefore, many teacher training programs and professional development initiatives integrate technology, with educational aims, into the courses to develop pre-service teachers' knowledge of technology (Katic, 2008; Koehler & Mishra, 2005). More research studies are needed to construct a framework and a theory to develop PSTs Techno-Pedagogical Content Knowledge (TPACK). The effective

implementation of educational technology requires teachers' internalization of educational technology. In this sense, teacher-training programs play an important role to have PSTs use educational technology in the teaching and learning process. Note that Niess, van Zee and Gillow-Wiles (2011) stressed that prospective teachers should gain experience in educational technology via the courses they take during undergraduate teacher education program. Özgün-Koca, Meagher and Edwards (2010) also argue that educational institutions are expected to provide PSTs with adequate knowledge and skills to use educational technology as an effective tool in their teaching practices. Analysis of the research on teachers' knowledge of technology indicates that there is need for well designed courses and field experiences to help pre-service teachers obtain techno-pedagogical knowledge about mathematics and conceptual understanding related to the use of technology in mathematics classrooms. Moreover, teacher training programs need to go beyond merely training teachers in how to use specific software in mathematics education, and they need to follow pre-service teachers' development of techno-pedagogical content knowledge to recognize their strengths and weaknesses in implementing technology based lesson. They need to have pre-service teachers reflect on their technology based implementations in terms of effectiveness. Therefore, assignments given as part of university coursework can be a means to require PSTs to examine these issues related to the use of technology for incorporating technology in the courses they will eventually teach.

To improve PSTs' TPACK, Niess (2006), suggested teacher-training programs provide teaching experiences to PSTs via technology in field experience course. The main concern of the researcher was the need for teacher development in a classroom environment where technology effectively used in elementary mathematics classrooms. The field experience and PSTs' reflections on these experiences were two crucial professional development tools used in the development of TPACK in this study. It was aimed to contribute to the literature on what teachers gain from implementing technology based lesson in real classroom context and reflecting on what they learn to

their practice. It is expected that via these experiences, pre-service teachers could link between theory and practice. Moreover, they would be ready for the possible difficulties they encounter during their initial years in technology based mathematics classroom.

In conclusion, the significance of this study arises from providing detailed information about the contribution of the field experiences and reflection-on-action process on (1) PSTs' TPACK levels in different teaching experiences specific to designing and preparing teaching aids; (2) changes and adaptations made by three PSTs in their TPACK level development through of the implementation of three technology-based lessons during a field experience; and (3) PSTs' interpretations of their experiences with educational technology throughout the implementation of three lessons in a field experience.

### **1.3 Definition of Important Terms**

*Pre-service Elementary Mathematics Teachers:* Pre-service elementary mathematics teachers are students who are enrolled in the four-year undergraduate teacher education program to be elementary mathematics teacher. In this study, pre-service elementary mathematics teachers refer to senior pre-service elementary mathematics teachers in 2011-2012 academic term at METU.

*Technological Knowledge (TK):* Knowledge about certain ways of thinking about, and working with technology, tools and resources. This includes understanding information technology broadly enough to apply it productively at work and in everyday life, being able to recognize when information technology can assist or impede the achievement of a goal, and being able continually adapt to changes in information technology (Koehler & Mishra, 2009). In the present study the specific educational technology used by the participants was GeoGebra and Spreadsheet. Technological knowledge refers to pre-

service teachers' technical knowledge about Geogebra and Spreadsheet software technologies.

*Technology Pedagogy and Content Knowledge (TPACK)*: Koehler and Mishra (2009) defined TPACK as;

underlying truly meaningful and deeply skilled teaching with technology, TPACK is different from knowledge of all three concepts individually. Instead, TPACK is 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 (p.66).

In this study TPACK refers to effective usage of Geogebra and Spreadsheet software technologies in mathematics education. In addition, in the present study, Techno-Pedagogical Content Knowledge used with Technology Pedagogy and Content Knowledge acronym.

*Reflection-on-action process*: It is a professional development method (Osterman, 1990, p. 134), enables individual thinking back on what had been accomplished and reviewing the actions, thoughts, and product. The experience of this study was pre-service teachers' technology-based lesson implementations. Pre-service teachers were asked questions to criticize their technology based lesson implementation experience and what they learnt from this experience.

*Facilitator*: The person who administers the reflection-on-action process via asking questions to PSTs to assists them reflect on the common objectives without taking a particular position or expressing a point of view during the interview.

*Field Experience:* It is an experience that PSTs observe and implement mathematics lesson in a real-classroom setting. In the content of this study PSTs had experiences implementing technology-based mathematics lessons.

*Mentor Teacher:* Mathematics teachers working in collaborating school, provide information to PSTs about school, school policies and practice, serve as role models in the classroom, and assist PST in lesson implementation process.

## **CHAPTER II**

### **LITERATURE REVIEW**

This study is mainly related to teacher knowledge for teaching mathematics using technology. More specifically, the theoretical framework of this study is centered around two fundamental approaches to teachers' mathematical knowledge; namely, Shulman's (1986) categorization of teacher knowledge and Ball, Thames, and Phelps (2008) categorization of knowledge for teaching, and Koehler and Mishra's (2005) categorization of Techno Pedagogical Content Knowledge (TPACK). This review of the literature addresses the theoretical background of teacher knowledge, Technological Pedagogical Content Knowledge, and the integration of technology into teacher training. The last section reviews the use of dynamic geometry software in mathematics education.

#### **2.1 Theoretical Background of Teacher Knowledge**

A large body of research has established that teacher knowledge is an important component in the teaching of mathematics because knowing how to make the subject matter understandable for the students makes for effective teaching of the subject matter (Ball et al., 2008). There are many researchers interested in teacher knowledge and there are many different approaches in categorizing teacher knowledge (Ball, 1990, 2000, 2002; Grossman, 1990; Hill, Ball & Schilling, 2008; Shulman, 1986). However, there is ultimately no consensus on clear-cut components describing teacher knowledge. This is because of the nature of teacher's knowledge. To quote Fennema & Franke (1992), "It is a large, integrated, and functioning system whose components are difficult to isolate" (p. 148). The categorization developed by Shulman (1986) is widely used by researchers.



According to his categorization, teachers' knowledge for teaching has three aspects, namely subject matter knowledge, pedagogical content knowledge, and curricular knowledge. Subject matter knowledge is the knowledge related to content that "requires knowledge of the facts or concepts of a domain" (Shulman, 1986, p.9). Subject matter knowledge refers to teachers possessing the knowledge of facts, concepts and truths in their subject area and being able to explain why these concepts are important to learn, and what the relationship is between these and other concepts (Shulman, 1986). The second aspect is pedagogical content knowledge, which relates to subject matter knowledge for teaching. Pedagogical content knowledge includes several different aspects of teaching knowledge. For example, regularly taught topics in the teacher's specialty field, the form of representations needed to present those ideas, powerful analogies, illustrations, examples, explanations and the ways of representing and formulating the subject in order make it comprehensible to others (Shulman, 1986). It also involves knowledge of the hard points and easy points of specific topics and how to recognize the students' level of understanding (Shulman, 1986). The third area of knowledge is curricular knowledge, which includes how well the teachers know the programs that have been prepared for the teaching of specific subjects and topics at any given level, the diversity of instructional materials available relating to those programs, and "the set of characteristics that serve as both indications and contraindications for the use of particular curriculum or program materials in particular circumstances" (Shulman, 1986, p.10).

Drawing on these three knowledge domains, namely subject matter knowledge, pedagogical knowledge and contextual knowledge, Grossman (1990) further defined Pedagogical Content Knowledge (PCK). According to Grossman (1990) PCK has four key components;

- An overarching conception of what it means to teach particular content topics.

- Knowledge of the way students understand and think, and how they learn particular subject matter topics.
- Knowledge of the curriculum and curriculum materials with respect to learning and teaching subject matter topics.
- Knowledge of instructional strategies and representations for teaching and learning particular content topics (Grossman, 1990).

Ten years later, researchers continued to explore PCK. Gess-Newsome (2002) examined pedagogical contextual knowledge and suggested two different models: transformative and integrative. According to the integrative model, pedagogical content knowledge is not a domain of knowledge; instead it is an intersection of categories. This model offers to develop subject matter, pedagogy and contextual knowledge independently and then integrate the three of them in the act of teaching. In this model, teaching is a presentation of content to learners in some context using an appropriate form of instruction. To create effective learning opportunities for students an expert teacher integrates subject matter, pedagogy, and contextual knowledge as needed (Gess-Newsome, 2002). According to the transformative model, regardless of the subject matter, pedagogy and contextual knowledge may be developed separately or jointly. In order to be an effective teacher all knowledge types need to be a synthesis of PCK. The transformative model requires the identification of prominent examples of PCK in practice. PCK should be evenly structured and easily accessible. PCK is the transformation of other knowledge and it is a unique form that impacts teaching practice directly. Integration of knowledge versus the transformation of knowledge is the main difference between these two models.

Based on these studies, the specific types of the knowledge needed by mathematics teachers were expounded by Hill and Ball (2004). They detailed Shulman's teachers' knowledge and suggested the categories 1) specialized knowledge of content, 2) common knowledge of content, 3) knowledge of content and students, 4) knowledge

of content and teaching and 5) knowledge of curriculum. On the one hand, common knowledge of content refers to a good command of general mathematics, which is necessary for solving mathematical tasks; on the other hand, specialized knowledge of content refers to the knowledge of teaching mathematics for comprehension. To connect students with content effectively Ball and Cohen (1999) impress on the need for knowledge of pedagogy (Ball & Cohen, 1999), “In order to connect students with content in effective ways, teachers need a repertoire of ways to engage learners effectively and the capacity to adapt and shift modes in response to students” (Ball & Cohen, 1999, p. 9). Ball et al. (2008) use a model to display domains of mathematical knowledge for teaching. In this model, subject matter knowledge and pedagogical content knowledge are broken down into six different components (Figure 2.1).

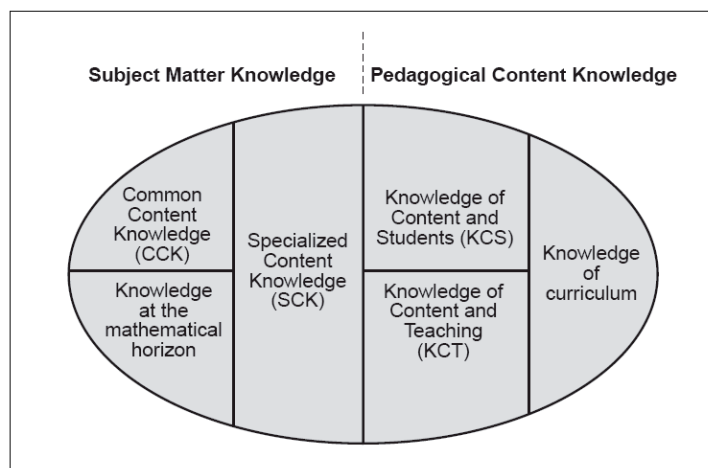


Figure 2.1 Domains of mathematical knowledge for teaching (Ball et al., 2008, p. 403)

Previous theories that have been reviewed so far discuss teacher knowledge without a specific technology component. Up to the year 2000 existing technologies were not very specific to the teaching area and the general technology proficiency that teachers needed to possess was included into pedagogical content knowledge. Therefore,

teacher education programs should include the specific technologies associated with their study area in their curriculum in order to teach PSTs how to use technology in their teaching activities. Currently, given the way technology is improving it is inevitable that technology will be used in education. In addition to having subject matter knowledge, pedagogical content knowledge and the skills to apply the curriculum based on this knowledge, teachers also need to have techno-pedagogical content knowledge (Pierson, 2001). Research studies and large-scale meta-analyses of these studies (e.g., Bernard et al.; Dillon & Gabbard, 1998; Fabos & Young, 1999) have clearly confirmed that educational technology has not reached its full potential back in the early 2000's. The next section focuses on the addition of technology to the knowledge required for teaching.

## **2.2 Techno-Pedagogical Content Knowledge (TPACK)**

Technological Pedagogical Content Knowledge (TPACK) as a type of teachers' knowledge needed by teachers in order to integrate educational technology in the teaching of specific subject matter topics was described by Koehler and Mishra in 2005 based on the Pierson (2001) studies. The TPACK framework provides a theoretical model of teacher knowledge to guide researchers in development of teacher knowledge for teaching via educational technologies (Koehler & Mishra, 2008). The TPACK framework comprises three basic knowledge constructs that teachers have: namely Content Knowledge (CK) knowledge of subject matter, Pedagogical Knowledge (PK) knowledge of teaching methods and learning, and Technological Knowledge (TK) knowledge of technology and technological tools. It also consists of four other types of technology integration knowledge that are derived from the connections between technological knowledge, pedagogical knowledge, and content knowledge. These are: Technological Content Knowledge (TCK) knowledge of how to use technology to put across the subject matter; Technological Pedagogical Knowledge (TPK) knowledge of

how to use technology to apply different teaching methods; Pedagogical Content Knowledge (PCK) knowledge of teaching methods with respect to subject matter content (Koehler & Mishra, 2009; Koh & Divaharan 2011). Mishra and Koehler (2006) conceptualized the TPACK framework presented in Figure 2.2 (Koehler & Mishra, 2005; Mishra & Koehler, 2006, 2008; Niess, 2005, 2006). The term TPACK was written TPACK to begin with but this was eventually changed to TPACK in order to make pronunciation easier. In addition, Jaipal and Figg 2010 expanded TPACK as “Total PACKage” meaning the total knowledge required by teachers to integrate technology in teaching effectively.

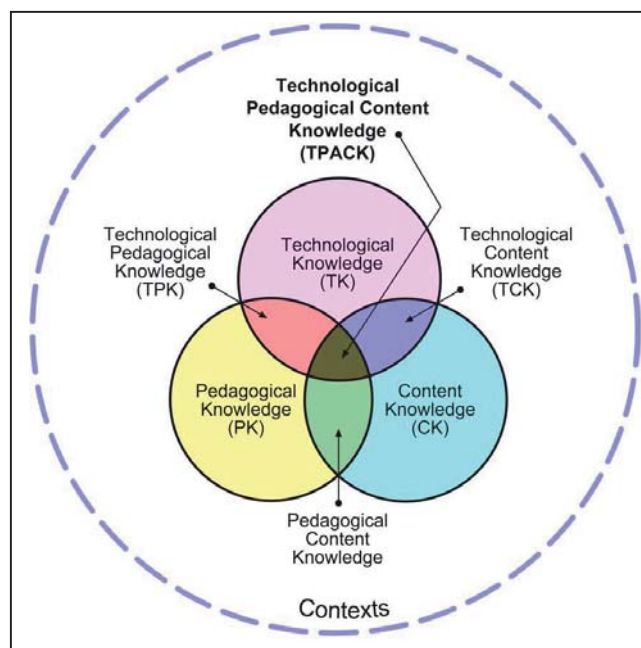


Figure 2.2 The TPACK framework and its knowledge components (Koehler & Mishra, 2009, p. 63)

In order to develop PSTs' TPACK, teachers should have prerequisite knowledge in content, pedagogy and technology (Koehler & Mishra, 2008). With the addition of technology into teacher knowledge three new knowledge types emerged, namely Technological Knowledge (TK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK). Technological Knowledge means proficiency in general information technology expected of 21st century people. Knowing how to use computer technologies, internet, smart boards, projection, smart phones etc. are all examples of technological knowledge. Teachers should be familiar enough with information technology as to be able to apply it effectively in their work and everyday lives. Teachers should be able to follow innovations in technology and adapt their skills to use these innovations in the classroom (Mishra & Koehler, 2006). In this study, technological knowledge refers to the technical usage of the dynamic geometry program. To participate in this study PSTs should have the technical skills to use the GeoGebra dynamic geometry program in mathematics education.

Technological Content Knowledge (TCK), meaning the interaction between content, pedagogy and technology, is critical for developing appropriate technological tools for educational purposes. Technological Content Knowledge is knowing how knowledge of technology and knowledge of content interact with each other. While designing a lesson content and technology are often considered separate from each other (Harris, Mishra & Koehler, 2009). There is a relationship between subject matter content and subject-specific educational technology that learners and teachers can and do use in the classroom. The advent of the new technologies changed the nature of instructional methodologies in order to use educational technologies effectively. Teachers should have the ability to choose the technology best suited to the subject matter content (Harris et al., 2009). Teachers should possess *creative flexibility* in order to use technology for specific pedagogical purposes (Harris et al., 2009). TCK focused on the knowledge of a given discipline and the impact of technology on teaching and learning (Koehler & Mishra, 2009). For example, teachers need to understand representations that can be

constructed and/or changed through the application of particular technologies. Teachers need to understand which kind of technology is best suited for addressing the given subject matter (Koehler & Mishra, 2009). In this study, technological content knowledge refers to designing technology-based lesson plans using the GeoGebra program.

Technological Pedagogical Knowledge (TPK), or the interaction between content, pedagogy, and technology, is an understanding of how teaching and learning can be designed when a specific technology is used (Koehler & Mishra, 2009). Technological Pedagogical Knowledge is specifically concerned with using educational technology in teaching via applicable teaching methods. Teachers should have the ability to use technology with educational purposes such as Microsoft Office, blogs or podcasts (Harris et al., 2009). In this study, technological pedagogical knowledge refers to designing technology-based lesson plans using the GeoGebra program. Teachers should possess *creative flexibility* in order to be able to use technology for specific pedagogical purposes (Harris et al., 2009).

The centerpiece of the framework, Technological Pedagogical Content Knowledge (TPACK) is different from knowledge of all three concepts individually. Technological Pedagogical Content Knowledge refers to interactions among content, pedagogical, technological, and content knowledge (Mishra & Kohler, 2006).

TPACK is 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 (Koehler & Mishra, 2009, p. 66).

Teacher knowledge for the effective integration of technology requires the transformation of knowledge into techno-pedagogical forms. Teachers should determine which forms of representation of the subject area are the most useful, which are the most

powerful analogies, illustrations, examples, explanations, and demonstrations in a word, and how to represent and formulate the subject so as to make it comprehensible to students. Teachers should have the technological skills to transform this knowledge into technology-based activity using most applicable instructional strategies for the subject matter topic, as Shulman (1986) argued for PCK.

The Gess-Newsome (2002) integrative and the transformative approaches to the nature of PCK might also help understand the TPACK model (Graham, 2011). The integrative perspective defines PCK as the combination or mixture of different types of knowledge. The transformative perspective, a holistic approach, on the other hand, considers PCK as a new synthesized form of knowledge that cannot be explained by the sum of its parts.

The explanation of this model implies that TPACK is different from knowledge of all three concepts individually. This approach considers TPACK a new and synthesized form of knowledge that is more than the sum of its parts. In conclusion, TPACK is a transformative understanding of the constructs because it is a unique body of knowledge synthesized from the integration of technological knowledge, content knowledge, and pedagogical knowledge (Angeli & Valanides, 2009).

The TPACK framework currently uses a Venn diagram representing an integrative model while in the explanations of TPACK in literature by Mishra and Koehler (2006) the transformative model is seen (Graham, 2011). In this study the development of TPACK was investigated using a holistic approach based on the transformative model. Transformative and integrative model presented in Figure 2.3.



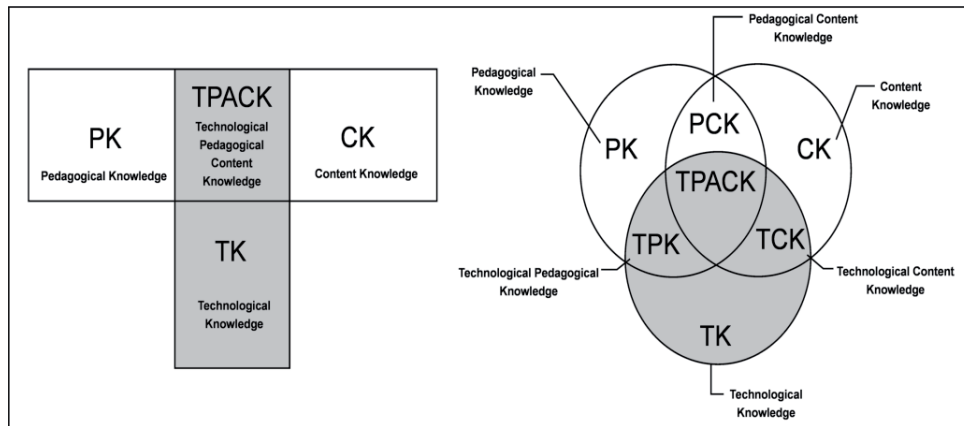


Figure 2.3 Models for combining PK, CK and TK (Graham, 2011, p.1957)

### 2.3 Developing a Pre-service Teachers' TPACK

TPACK is an important body of knowledge for teaching mathematics that must be developed in the coursework for teaching and learning as well as in the coursework aimed at developing mathematical knowledge (Niess, 2006). TPACK includes vital qualities of teacher knowledge. How mathematics teachers acquire TPACK and integrate it into mathematics education effectively is a controversial issue. Mishra and Koehler (2006) TPACK approach was not subject specific in the field of educational technology. Research in mathematics education also focused on how to use educational technology effectively in the mathematics classroom (Kaput, 1994; NCTM, 1980). Niess (2005) further defined TPACK in order to integrate technology in mathematics education based on the Grossman (1990) four-component PCK. She (2005) added technology to each component of Grossman (1990) for TPACK for mathematics teachers as the knowledge and beliefs that teachers demonstrate. Niess (2005) added these bold-type words into the guidelines.

- An overarching conception of what it means to **integrate technology** to teach particular content topics;

- Knowledge of students' understandings, thinking, and learning of particular subject matter topics **with technology**;
- Knowledge of curriculum and curricular materials **that integrate technology** with learning and teaching subject matter topics;
- Knowledge of instructional strategies and representations for teaching and learning particular content topics **with appropriate technologies** (Niess, 2005, p.4).

This perspective provided an overview for teacher training programs in terms of how to give PSTs an overarching concept of teaching with technology, pedagogy, and content (Niess et al., 2009). “An overarching concept about the purposes for incorporating technology in teaching subject matter topics” is a component concerning PSTs’ instructional decisions. It is related to what the teacher knows about the nature of the subject, what is important for students to learn, and how technology supports their learning. “Knowledge of student understanding, thinking, and learning in subject matter topics with technology” is a component concerning PSTs’ knowledge of student understanding and thinking with technologies in specific mathematical topics. “Knowledge of curriculum and curricular materials that integrate technology in learning and teaching subject matter topics” is a component related to PSTs’ knowledge about the curriculum and technologies for teaching specific mathematics topics. “Knowledge of instructional strategies and representations for teaching and learning subject matter topics with technologies” is a component related to PSTs’ adaptation of their teaching to guide students how to learn about specific technologies at the same time as they are used in learning mathematics (Lyublinskaya & Tournaki, 2011).

Later, the theories continued by defining a five-stage developmental process for TPACK (Niess, Lee & Sadri, 2007). In 2009, this five-stage model was presented to the Association of Mathematics Teacher Educators’ (AMTE) Technology Committee in order to illustrate the integration of technology in teaching and learning mathematics.

This model published by Niess et al. (2009) is based on Rogers' (1995) model of the innovation-decision process. This TPACK development model for mathematics teachers can be used in describing and evaluating their TPACK growth (McBroom, 2012). A visual description for the five stages of TPACK integration was shown in Figure 2.4 (Niess et al., 2009, p.10).

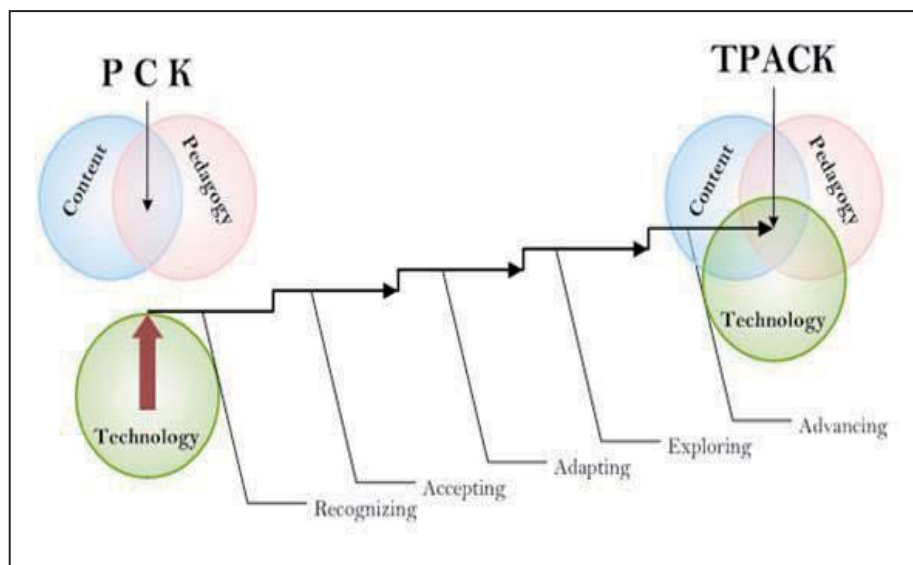


Figure 2.4 Five stages for integrating technology in teaching and learning mathematics (Niess et al., 2009, p. 10)

The five stages in this model are: recognizing, accepting, adapting, exploring, and advancing. This model consists of four themes: curriculum and assessment, learning, teaching, and access. At the end researchers provided descriptors and examples to give an idea about the actions teachers engage in “while adapting technology in their teaching in order to enhance student learning” (Niess et al., 2009, p. 12). According to this model, when learning to integrate a particular technology in teaching and learning mathematics, the five-stages of developmental process are:

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 (Niess et al., 2009, p. 9).

Niess (2005) definition includes the teacher knowledge of incorporating technology in teaching mathematics. As teachers progress along this model from the level of recognizing through accepting, adapting and exploring to advancing, TPACK forms and expands each of the four major themes each time they use educational technology (Niess et al., 2009). This model can assist in identifying the level of teachers' knowledge related to integrating technology into teaching and in providing insights into knowledge growth (McBroom, 2012). In the following studies, Lyublinskaya and Tournaki (2011) combined Niess et al. (2009) four components with the five-stage development process created by Niess et al. (2007), and they constructed a rubric to analyze the development of PSTs' TPACK in mathematics education. In this study this rubric was used to investigate PSTs' lesson performance. Detailed information about this rubric is given in Chapter III.

Mouza and Karchmer-Klein (2013) stated that TPACK should not be considered only at a theoretical level, but rather it needed to be examined in practice. In order to obtain an overall picture of pre-service teachers' TPACK, lesson plans must be assessed together with their implementation in the classroom.

Further studies focused on the implementation of technology-based lessons in the classroom to develop teachers' TPACK. Recent studies in teacher education emphasize the need to design programs that increase PSTs' abilities to reflect their practices (Grossman, Hammerness & McDonald, 2009; Lunenberg & Korthagen, 2009; Mouza & Karchmer-Klein, 2013).

The model they used was a large-scale, cross-national study. It created an explanatory model of factors shaping the use of technology for pedagogical purposes named TPACK-in-Practice. The TPACK-in-Practice model includes aspects of TPACK that occur within the broader context of the classroom. They re-envisioned a model of TPACK that helped create the framework for technology professional development workshops for teachers. Their synthesis of current research resulted in four design elements useful for developing learning opportunities for teacher development for TPACK-in-Practice. The recommendations found in this model were well crafted due to the focus on didactical modeling, tool use, and skill practice.

#### TPACK-in-Practice Guidelines:

- Modeling a technology-enhanced activity type (learning with a tool) to set the context and purpose for tool use.
- Integrating pedagogical dialogue in a modeled lesson.
- Developing TK (in context) through short tool demonstrations.
- Applying acquired technical skills and knowledge in additional practice tasks using the activity type (Jaipal, Figg & Burson, 2012, p. 4712).

The Framework of TPACK-in-Practice is presented in Figure 2.5. The framework identifies teacher knowledge in practice in the first column, their characteristics in the second column and examples of action in the third column related to technology usage in education.

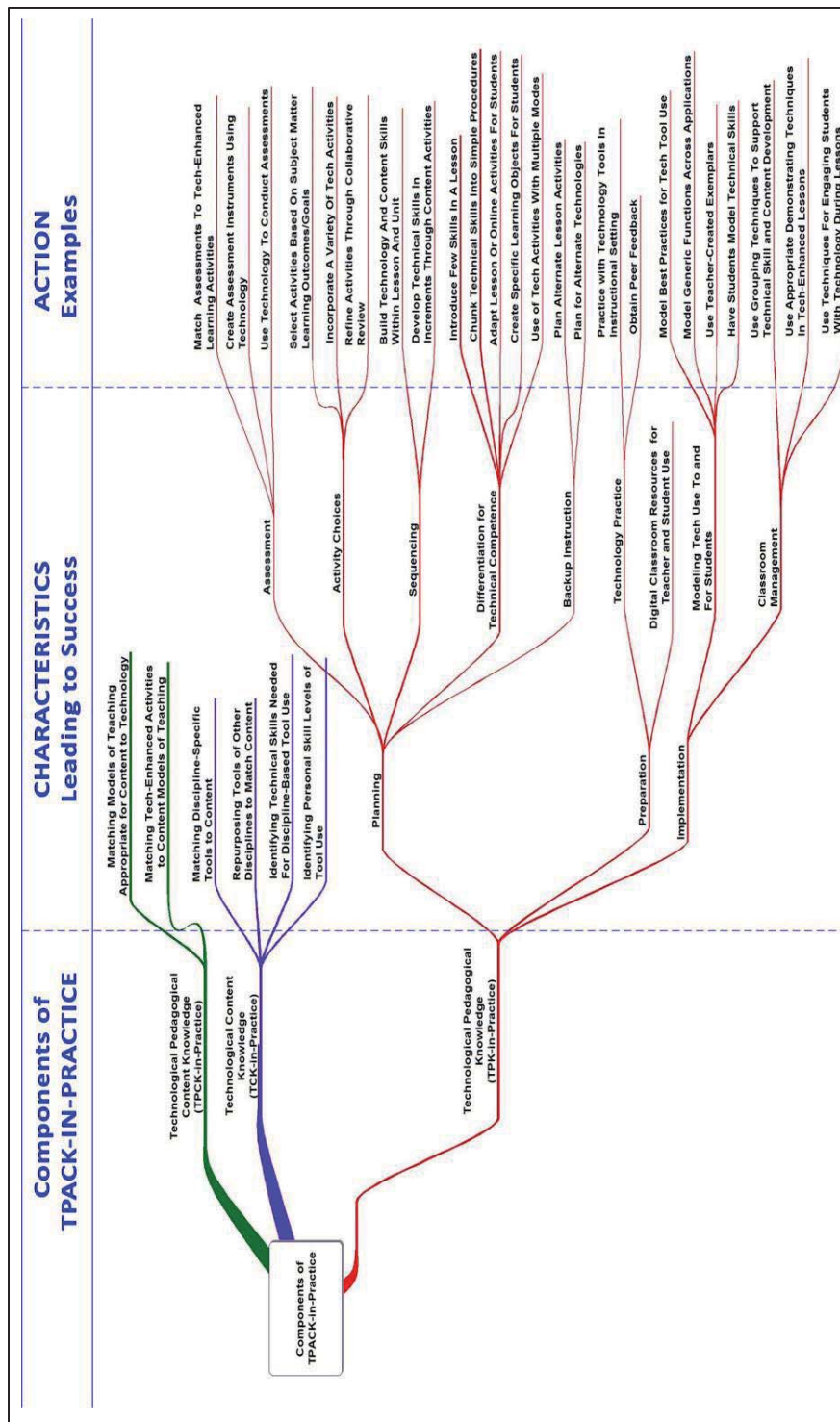


Figure 2.5 The framework of TPACK-in-practice (Jaipal et al., 2012, p. 4717)

However, most pre-service teachers are unable to integrate what they learn from teacher education programs into their future teaching practice. Consider balancing technological/pedagogical training with experiences of classroom observation, implication and reaction. A methodology used to support the development of TPACK is found in the Situated Technology Integration (SiTI) model (Hur, Cullen & Brush, 2010). The SiTI model expands the workshop format to include aspects of TPACK that occur within the broader context of the classroom. An emphasis on reaction and beliefs regarding the meaningful implementation of technology is emphasized in the guidelines (*italics were added by the researchers*).

#### SiTI Guidelines:

- Provide concrete experiences: To assist pre-service teachers in understanding the relationship between theory and practice, various examples and concrete experiences should be provided.
- Promote Reaction: To facilitate knowledge construction, in-depth and ongoing Reaction should be promoted with assistance from teacher educators.
- Assist in application: To help pre-service teachers apply knowledge learned in real situations. Opportunities to observe expert teachers' classrooms and *then apply that knowledge in classrooms* should be included.
- Create communities of learners: To assist pre-service teachers in examining prior beliefs, sharing new ideas with peers and other educators should be encouraged.
- Develop Technological Pedagogical and Content Knowledge: To successfully integrate technology into their future classes, pre-service teachers should be called on to develop plans to use their technological knowledge in a meaningful way in relation to their content and classroom teaching knowledge (p. 167).

These SiTI guidelines provide information about the role of the teacher educator in pre-service teacher development of TPACK. To position these guidelines in their teacher



preparation program Hur, Cullen and Brush (2012) developed a three-phased approach (preparation, exploration and implementation). They readily acknowledge the difficulties in providing pre-service teachers with field experience as part of a mathematics methods course. These guidelines were used in the framework implementation process of this study. The researchers focused particularly on the following guidelines: *Promoting Reaction* and *Developing Technological Pedagogical and Content Knowledge*. To promote reaction, researcher conduct, reflection-on-practice, and to develop TPACK the PSTs were given the chance to carry out technology-based lessons. Detailed information about the field experience and reflection-on-practice is given in the next section.

#### **2.4 Field Experience and Reflection-on-Practice Process**

The question of how PSTs can put theoretical knowledge into practice is a hot topic in the teacher education research studies (Bobis, 2007). Darling-Hammond (2010) stated that “it is impossible to teach how to teach powerfully by asking them (PSTs) to imagine what they have never seen or to suggest they “do the opposite” of what they have observed in the classroom” (p.42). Field experience is a crucial setting for connecting theory and practice (Wentworth, Waddoups & Earle, 2004; Zeichner, 2008). Literature indicates that field experience provides PSTs with an *authentic context* for thinking about, designing, implementing, and assessing the impact of integrating technologies in learning mathematics (Niess, 2006). In field experience PSTs have the chance to observe the nature of classroom settings. They gain teaching experiences in a real classroom context. They can explore school culture and create a sense of self as a teacher (Hur, Cullen & Brush, 2012). Since field experience provides a space for PSTs to practice instructional strategies that integrate technology, content, and pedagogy, Zeichner (2012) claimed that teaching practices help PSTs develop the professional vision and skills in this process. Carrying out technology-based lessons in practice is

vitaly important for developing PSTs' TPACK since the planning of technology-based activity and then its practice in a real classroom context gives PSTs the chance to hone their skills and learn from practice (Darling-Hammond, 2010; Hixon & So, 2009; Mouza & Wong, 2009). This viewpoint claims that field experience help teachers to notice, distinguish, discuss, unify, and implement TPACK activities in curriculum standard-based instructional design (Harris, 2008). The practice of field experience in teacher training has the potential for giving PSTs a new understanding of technology integration in mathematics education. Zeichner (2008) stressed the lack of formal class-work preparation in instructional practices and said that the professional aspect of being a teacher was learnt on the job in teacher education. Therefore, teacher preparation programs need to challenge the PSTs by have teaching experiences with technology (Niess, 2006). Increasing the teachers' subject-specific experience involving the integration of technology in their field helps to develop their TPACK (Niess, 2006). Teacher preparation programs need to go beyond merely training teachers in how to use specific software and hardware tools in education, and focus on developing an understanding of the complex set of interrelationships between artifacts, users, tools, and practices (Mishra & Koehler, 2006).

In the early 70's Schön conducted studies on "what makes professional practice effective"(Pakman, 2000, p.5). Then in order to challenge PSTs in their teaching experience he (1983) suggested the theory of reflective practice in teacher education. The origin of the reflective framework was Dewey's (1933) theory of reflective thought and action. This theory includes phases of reflective learning and is especially used for problem solving. Reflective practice was "challenging, focused, and a critical assessment of one's own behavior as a means towards developing one's own craftsmanship" (Osterman, 1990, p. 134). Reflective practice, by monitoring the level of professional actions as a means of professional development, was favored by teacher educators (Osterman, 1990; Verloop, 1999). The main aim of the reflection process is to develop teachers' reasoning about why they use certain instructional strategies

practically and how they can improve their teaching skills (Lee, 2005). In field teaching PSTs reflect on their experience. They reason why it is they employed certain instructional strategies and they figure out how they can improve their teaching (Lee, 2005). Niess (2006) stated that this practice requires PSTs to notice when, where, and how technology enhanced their teaching. Reporting on their own efforts strengthen their teaching via technology (Mouza & Karchmer-Klein, 2013). Reflective practice used to validate knowledge obtained from teaching experience includes two types of reflection: reflection-in-action and reflection-on-action (Giaimo-Ballard & Hyatt, 2012). Reflection-in-action takes place during the lesson when PSTs reflect on classroom interactions when in their classrooms (Zeichner, 2007). Reflection-on-action takes place after the lesson. Teacher educators raise many questions about PSTs' existing practices in using cases from the lesson and they interpret a clearer understanding of PSTs' teacher knowledge. Giaimo-Ballard and Hyatt, (2012), stated that the reflection process drives PSTs to analyze their own practice, which results in changes in their teaching and redesigns how they approach the use of technology as a teaching tool. It also seeks to capture insights and lessons learned by participants in the process of designing, enacting, and reflecting on their own technology-integrated classroom experiences (Mouza & Karchmer-Klein, 2013). Such skills are critical for learning-how-to-learn from teaching and engaging in continuous professional growth (Korthagen & Kessels, 1999; Schön, 1983). Reflection-on-action is the practice in which PSTs notice the interaction and integration of content, pedagogy and technology in ways that ultimately affect their teaching. Use of the reflection-on-practice process during field experience courses helps PSTs develop their TPACK. Therefore, in their professional preparation, teachers need to engage in reflection-on-practice.

In his study Lee (2005) examined and assessed the changes in pre-service teachers' reflective thinking as they gained field experience. He reviewed the criteria for assessing reflective thinking, and investigated how the process of reflective thinking develops in pre-service teachers' knowledge. The participants of the study were juniors

in a secondary school mathematics education program. Data for the study were collected from interviews and observations, and from written documents such as survey questionnaires and journal entries. Pre-service teachers was observed and videotaped while carrying out mathematics lessons. Afterwards, the pre-service teachers watched their videotaped lessons and reflected on their teaching in interviews and in writing. The investigation of the participants' reflective thinking indicated that the changes in their reflective thinking could be attributed to experience, mode of communication (oral versus written), the content of their reflections, and the protocols of the dialogue/questions. The findings of the study implied that continued practice and coaching is important continued in improving PSTs' reflective thinking. Reflective thinking activities increase PSTs' awareness and understanding of themselves as a teacher. Through reflective thinking pre-service teachers can challenge and apply themselves to increase their teaching performance. In addition, reflective thinking enables pre-service teachers to think about what the teacher's role is before they go into the field. Therefore, it is important to present various reflective thinking opportunities to pre-service teachers in a teacher education program.

In another study conducted by Dietz and Davis, (2009) pre-service teachers were asked to work on vignettes describing a teacher's decision-making process with regard to lesson plans. During the third semester of an undergraduate teacher education program in the United States. 40 senior pre-service teachers for Assignment 1 and 36 senior pre-service teachers for Assignment 2 participated in the study. The reason for the decrease in the number of participants was that some assignments had not been completed. The data was collected via reflective journal assignments during an elementary science methods course. In the first assignment the pre-service teachers were asked to look at the two teachers pictured in the 3–5 weather unit, Emily and Nancy. For the second assignment, the pre-service teachers were asked to examine the images of any of the other four teachers pictured. Then researchers asked reflective questions e.g., what do you think of the changes the teachers made to the lesson that you are

emphasizing? How did the teachers learn about and use their students' ideas? How might you use these examples of inquiry to help you figure out the changes you would make to the lesson? Afterwards, the pre-service teachers reflected on the vignettes. In this process the researchers helped participants to define their own perspectives on inquiry-oriented science teaching. What they expected was that the elementary teachers would begin to understand inquiry-oriented science teaching in the vignettes and identify ways of incorporating it into their own lesson plans for future classrooms. Then, the PSTs carried out lessons and gained experience. Afterwards, the pre-service teachers wrote a second reflection paper for the second vignette and they answer the questions: Why did they choose that teacher teacher? What did they think of the decisions he or she made? Whether they have had similar dilemmas in their teaching or planning? etc. The results of the study implied that answering these questions would promote productive reflection among the pre-service teachers. These papers also gave teacher educators insights about pre-service teachers' knowledge of teaching. In these papers pre-service teachers shared their ideas about teaching, added ideas, integrated those ideas with others and further developed their own identities as teachers.

However, despite support for the important role of reflection in teacher education, evidence is lacking regarding the ways in which pre-service teachers may link ideas related to technology, content, and pedagogy through technology-based lesson implementation experience. In accordance with "promote reaction" in SiTI guidelines, this study focused on the use of reflection-on-practice as a means for fostering PSTs personal reflection relating to teaching in field experience via educational technology. It examined the extent to which reflection-on-action allows PSTs to recognize the interactions of technology, content, and pedagogy in their own practice. It is expected that this study contributed to the technology-based field experience and reflection-on-practice approach. In the next section TPACK studies were reviewed and the results of the TPACK development process were examined.

## 2.5 TPACK Studies

Technology has become an integral component of teaching and learning specific content. Improvements in educational technology make it necessary for teachers to be trained how to keep up with the technological opportunities in education. In order to integrate technology in their teaching teachers must develop knowledge of their subject matter with respect to technology and they need to understand what it means to teach using technology (Niess, 2006). This approach explains the type of technological qualifications that a teacher needs in order to be able to integrate technology in teaching effectively. However, measuring teachers' knowledge in using educational technology is problematic since the TPACK framework does not clarify the ways of developing, assessing, and measuring TPACK (Graham, 2011; Mouza & Karchmer-Klein, 2013).

In the previous research studies, both qualitative and quantitative methods were used to explore teachers' technological pedagogical content knowledge (TPACK). In studies that incorporate survey methods researchers tended to measure TPACK with Likert type questionnaires, which investigate PSTs self reports relating to components of TPACK (Archambault & Crippen, 2009; Schmidt et al., 2009).

Lin, Tsai, Chai and Lee (2013) conducted a study to investigate science teachers' perceptions of TPACK addressing teachers' perceptions of the affordances of technology application in instruction. A total of 222 pre- and in-service science teachers in Singapore participated in the study. A survey of pre-service teachers' Knowledge of Teaching and Technology developed by Schmidt et al. (2009) was used to collect data concerning science teachers' self-reported confidence in TPACK. Structural equation model analysis was utilized and the findings indicate that the seven-factor model of TPACK hypothesized in the literature is acceptable. The results confirm the seven-factor model and indicate that the science teachers perceived TPC significantly and that they positively correlated it with all the other TPACK factors. The findings indicate that

female science teachers perceive higher self-confidence in pedagogical knowledge but lower self-confidence in technological knowledge than males.

Bulut, (2012) in his study investigated the perceptions of pre-service mathematics teachers' TPACK concerning geometry. The sample of the study consists of 780 pre-service mathematics teachers. He developed Perceived TPACK for geometry as the instrument for data collection. The results of the study implied that pre-service mathematics teachers had high perceptions of TPACK with respect to geometry. Moreover, there was a statistically significant difference between male and female pre-service mathematics teachers in favor of male participants in terms of technological knowledge, technological pedagogical knowledge and technological pedagogical content knowledge.

Doğan (2012) conducted a study to explore Turkish primary school mathematics teachers' views about the use of computers in mathematics education. The sample of the study was 129 fourth-year prospective primary school mathematics teachers. He asked participants "What do you think about using computers in mathematics education? Please explain it in the light of your own experiences." The written response to this question was analyzed using qualitative techniques. The participants' answers were analyzed in terms of content as well as the technological and pedagogical aspects about computers. The results were classified into three main categories: 1) beliefs about the nature of mathematics, learning mathematics, and computers; 2) computers and their necessity, use and usefulness in mathematics as well as their abuse and misuse; 3) pedagogical aspects including affective dimensions. According to results of the study, the PSTs suggested teaching with computers. However, they complained about not having the advances skills needed to use educational technology in their teaching. They were only able to perform minor calculations with computers. They stated that improved use of computers might help them to both learn and teach mathematics more effectively. However, they did not feel confident about their ability to teach mathematics using computers.

Although those studies provide general information about PSTs' self reports for the various aspects of TPACK, they seem to miss some important factors such as explaining PSTs' techno-pedagogical skills through analysis of such elements as lesson plans, technological activity constructed by PST, feedback papers and observation of lesson implementations. Moreover, since PSTs' self-reports about their TPACK might not be consistent with their instructional practices all the time (Lawless & Pellegrino, 2007), studies that include the elements of teachers' TPACK, technology-based lesson implementations, in depth interviews etc. need to be made in order to interpret teachers' progress in terms of TPACK (Niess et al., 2007, 2009).

In their study Mouza and Karchmer-Klein (2013) used field experience and reflection strategies to develop PSTs' TPACK in various different cases. The participants of the study were 58, 3rd and 4th year pre-service teachers from different majors literacy and social studies, science, and mathematics. They had required participants to enroll in technology-based courses before the study. Then, researchers asked participants to design and reflect on their technology-integrated experiences (Mouza & Karchmer-Klein, 2013). During the study they completed the field experience course. Participants criticized their lesson plan with their cooperating teacher and received feedback. Then participants implemented technology-integrated lesson in their field experience and wrote a case report related to their experience in this process. Findings of the study indicated that analyzing and reflecting on technology-integrated classroom experiences helped participants identify important lessons related to technology and the nuance relationships among technology, content, and pedagogy. According to study, field experience was an opportunity for PSTs to engage in the educational technology as a professional by implementing their technology-based activities. Self-reports provided information about to participants designed particular lessons, what were they thinking in the process of planning, organizing, and implementing the lessons, and why they followed particular actions over others (Leatham, 2008). Upon the completion of the study participants implemented more



inquiry-oriented lessons that asked students to discover, investigate, and generate an artifact about their learning. Even if in some cases there was a disconnection between the lesson plan and the implementation of the lesson, findings of the study implied that teachers developed an understanding of the types of technology resources available for classroom teaching and learning, and the ways in which they can support curricular goals and instructional strategies.

In another study, Koh and Divaharan (2011) proposed a TPACK-Developing Instructional Model to foster teachers' TPACK development based on the five stages described by Niess et al. (2007). A seven-week training program, to teach PSTs the pedagogical usage of the Interactive Whiteboard, was designed by a higher education institute in Singapore in 2009. Program consisted of three instructional phases, each phase supported teachers to develop TPACK through activities that strengthen the connections among their technological knowledge, pedagogical knowledge, and content knowledge. In the first phase teachers observed the faculty members' usage of technology. In the second phase PSTs' built technical proficiency through computer skills instruction, technology integration, tutor demonstrations and pre-service teachers' hands-on exploration. In the third instructional phase PSTs asked to design technology-based projects. The data was collected through pre-service teachers' reflection papers about the phases. 63 reflection papers submitted in total. The reflections were coded for the different types of TPACK constructs. The results showed that this content specific technology training helped PSTs to formulate pedagogical strategies for using the Interactive Whiteboard. The results of the study implicated that PSTs developed their TPACK especially during Phase 3.

In their study Graham, Burgoyne, Cantrell, Smith, Clair and Harris, (2009) developed an instrument to measure in-service science teachers' TPACK. This instrument includes the TK, TCK, TPK and TPACK aspects of the framework. The researchers used mixed method techniques. Fifteen in-service teachers participated in the study. The participants enrolled in a 10-day course and filled out a survey two times

before and after the course. The course content included three phases of instruction. In the first learning phase teachers learned interactive classroom instruction for science in two days. In the second enacting phase the teachers studied science topics and how to carry out a full scientific investigation in field locations. In the third transfer phase teachers designed lessons and put them into practice. Afterwards, they reflected on these investigation lessons. The results of the study indicate there was an increase in the confidence level in teachers' TK, TPK, TPACK, and TCK. The researchers concluded that courses with content-specific educational technologies increase teachers' technical awareness and skills. These are a prerequisite to being able to meaningfully integrate technology into teaching and increase self-confidence.

Mudzimiri (2012) conducted a multiple-case study to develop pre-service mathematics teachers' TPACK. To develop the connections between technology, content and pedagogy, PSTs participated in a mathematics methods course, a technology-intensive and content-rich mathematical modeling course and a practicum course. Five pre-service teachers enrolled in the study. The data sources were: lesson plans, a TPACK survey with both open-ended and Likert-type questions, statements on the philosophy of teaching, weekly meeting notes with modeling and methods instructors, student teaching episodes, weekly instructor meeting notes and an exit interview. The participants developed four technology-based lessons for this study. The first two lessons were developed in groups while the third and fourth lessons were developed individually. The lesson plans were presented to the class for feedback, and revisions were made before applying them in the classroom. The lessons as applied were analyzed with a modified version of the TPACK levels rubric, developed by Lyublinskaya and Tournaki (2011). A detailed analysis of the results demonstrates that the development of pre-service teachers' mathematics TPACK is complex and that there are a number of factors in play, such as the pre-service teachers' prior experiences with technology, their mathematical backgrounds and their beliefs about the use of technology in mathematics instruction. The researcher collected multiple data sources to assess the development of

teachers' TPACK. The participants in the study designed technology based lessons and implemented them in the classroom. This study also determined a mismatch between the participants' self-reports about their TPACK and their actual TPACK. Realistically, not each of the lessons was designed effectively in terms of teaching with technology. Mudzimiri (2012) suggested that pre-service teachers need more personal experience with technology, so teacher preparation programs should integrate technology into the coursework.

Another study, was conducted by Niess (2005) with 22 pre-service science and mathematics teachers. The researcher used a multi-dimensional approach for the outline of the study: (1) research-based teaching and learning; (2) technology integration (TPCK); (3) PCK development; and (4) instructional practice integrated with campus-based coursework. As part of this study PSTs enrolled in courses. In these courses the PSTs learned how to use various educational technologies and how to integrate these technologies in their teaching. In addition, in the technology-based teaching activities they gained teaching experience. The cooperating teachers, university facilitators and the science and mathematics education faculty all challenged the PSTs to consider the curriculum and how technology supported the national standards. The participants were observed over the course of one year in order to collect data. The assignments that they prepared for the courses were collected and analyzed. In addition, facilitator and cooperating teachers' analyses relating to the PSTs' performance were collected; finally, the participants were interviewed about the various parts of the program. At end of the study the participants were asked to write a report about their lessons in practice with respect to each student's understanding of the science/mathematics concepts, how successfully technology was integrated into the lessons, and about their teaching while integrating technology in teaching science/mathematics. In the end 14 out of 22 students displayed an improvement in their TPACK according to assessments made by the facilitators, the cooperating teachers and the students themselves.

In another study Özmantar, Akkoç, Bingölbali, Demir, and Ergene (2010) investigated the development of pre-service mathematics teachers' use of multiple representations. The researchers developed two courses. The first one dealt with methods for teaching mathematics and second one involved technology-aided mathematics teaching based on the TPACK framework. The aim of these courses was to have PSTs develop skills in teaching mathematics with educational technology at secondary level. The educational technology used in the course was graphic calculus. The researchers designed hands-on activities to explore the technological content of the software in general and the technological content of the software for derivatives in particular. They implemented example technology-based activities to teach the concept of derivatives using graphic calculus. 40 pre-service mathematics teachers enrolled in these two courses and integrated technology in teaching derivative concepts. Multiple data collection techniques were used including: diagnostic test on derivative, lesson plans, teaching notes of microteachings, video records of micro-teachings, interviews and questionnaires. Analysis of the data implied that thanks to the study pre-service mathematics teachers had improved their knowledge of multiple representations, their usage of multiple representations in their teaching, and that they had made the connection how to use educational technology to teach mathematical concepts via multiple representations.

In their qualitative case study, Kinuthia, Brantley-Dias and Clarke (2010) investigated the potential of technology integration teaching cases in order to improve pre-service mathematics teachers' knowledge of technology-based mathematics education. Eight pre-service teachers who enrolled in the technology integration course participated in the study. In this course both problem-centered and activity-based approaches were implemented using educational technology in K-12 classrooms. In this course pre-service teachers designed technology-integrated lesson plans, technology artifacts, the prepared reflection papers and a portfolio for the content of the course. The participants discussed and wrote ten cases of teachers who had integrated technology in

their teaching. Data was collected via case responses, case reflections, course reflections, and focus group interview transcripts. Participants wrote three reflection papers about their expectations from course, their technical skills and self-efficacy in technology integration at the beginning, middle and end of the study. The results of the study indicated that at the beginning pre-service teachers' beliefs about educational technology was relatively negative when compared with the final reflection papers. Case-based learning with the help of reflective practice was perceived to support pre-service teachers' beliefs about the pedagogical usage of educational technology.

More research is needed to determine the effectiveness of reflection-on-practice in technology-based field experience course and to improve the theory and frameworks for professional development programs toward developing TPACK (Koehler & Mishra, 2008; Niess, 2006). In the present study the reflection-on-action process is used to improve PSTs' TPACK in the field experience course. The primary focus was on content-specific applications of technology in educational technology field. Specifically, was aimed at contributing to the existing body of knowledge about PSTs' teaching mathematics via GeoGebra technology integrated with content-specific pedagogy. It provided rich and holistic descriptions of the participants' TPACK in mathematics within the context of their field experience through reflection-on action process. In accordance with this aim, qualitative methods were used to examine the data for proving PSTs' improvement in the strategies they used to integrate technology in mathematics, how they dealt with problems, and their reactions to this process.

## **2.6 Usage of Dynamic Geometry Software in Mathematics Education**

Educational technologies, graphing calculators, computer algebra systems, geometry construction tools, networked and web-based learning environments all support and enhance teaching and learning mathematics (numbers, algebra, geometry

and measurement, data analysis statistics and probability). In the literature there are varied names for technology usage in education for example, ICT-TPACK for information and communication technology (Angeli & Valandis, 2009), TPCK-W for web technology (Lee & Tsai, 2010), technology-enhanced PCK (Niess, 2005).

Geometry is a complex network of concepts, ways of reasoning, and representation systems to conceptualize and analyze physical and imagined spatial environments (Battista, 2007). Geometry content includes shapes and properties, transformation, location and visualization (Van De Walle, 2007). Over the last decade, technology has played an ever-increasing role in teaching geometry, since it provides a rich variety of experiences that allow students to be actively involved in geometry education (McCoy, 1996). As a critical tool, Dynamic Geometry Programs have emerged to teach learners geometry content (Kondor, 2004; Lavicza & Papp-Varga, 2010; Whiteley, 2000). The term dynamic geometry was “originally coined by Nick Jackiw and Steve Rasmussen and has quickly entered the literature as a generic term” (Lehrer & Chazan, 1998; p. 349). Dynamic geometry software (DGS) is designed for teaching geometry in schools. “An accurate constructor for any ruler-and straightedge construction in Euclidean geometry” (King & Schattschneider, 1997, p.2) and isometries are available with dynamic geometry programs (Whiteley, 2000). DGS supports students in solving geometry problems involving mathematical proofs.

Dynamic geometry software has had a profound effect on classroom teaching (King & Schattschneider, 1997; Oldknow & Tetlow, 2008) and these dynamic software packages are vital in raising student awareness, challenging their conceptual understanding and motivating the synthesis of mathematical notions (Hollebrands, 2007; Kaput & Thompson, 1994; Peressini & Knuth, 2005). In recent years, one of the most common dynamic geometry program used in mathematics education is GeoGebra. Students are able to construct mathematical objects, create models and conduct interactive explorations using GeoGebra by dragging objects, tracing points, changing parameters and measuring objects. GeoGebra has three different representation menus:

graphics, numeric algebra and a spreadsheet. These three representations are dynamic and linked to each other (Hohenwarter & Hohenwarter, 2009). Therefore, GeoGebra facilitates the visualization of geometrical concepts and the explorations of their properties. It assists the observation of the relationships between geometrical concepts in a dynamic way.

Marrades and Gutiérrez (2000) conducted a study to investigate how dynamic geometry software usage could improve students understanding of the nature of mathematical proof and develop their proof skills. To this end the researchers described and analyze students' answers to proof problems in dynamic geometry environments. Analysis of the students' answers showed that dynamic geometry software provided an environment for them to conduct mathematical experiments and then check their solutions and guesses in the process of looking for patterns to find general properties. The dynamic geometry program includes non-traditional ways for students to learn and understand mathematical concepts and proofs. In the Battista (2002) study there was an example of the effective usage of interactive geometry software in helping students make sense of two-dimensional shapes. Battista (2002) determined a change in students van Heile levels of reasoning through discussion with Shape Makers software. Afterwards, the researcher gives some concrete examples to illustrate the potential for growth in geometric thinking afforded to students by working with Shape Makers Microworld. Shape Makers Microwold is a dynamic software that allows students to change a parallelogram on the screen by dragging vertices. This enables students to see the continuous transformation of one parallelogram and allows them to conjecture about shapes. Students can predict the movement of shapes by these activities and they are able to formulate and describe the geometric properties of shapes. Instead of memorizing the rules, this kind of dynamic geometry software gives a chance for students to work with the concepts actively in a visual way to explore the range of mathematical ideas and representations. For example, students may think that a rhombus is not a parallelogram. The Shape Makers such as the parallelogram maker, the rectangle maker, the rhombus

maker etc., enable students to conjecture about shapes and see the relations between them. It helps students to conceptualize the movement regularity with complete precision by expressing it in terms of geometric properties (Battista, 2002). In this way the students can see that every rhombus is a parallelogram but that only parallelograms with four equal sides are a rhombus. In their study, Hadas, Hershkowitz and Schwarz (2000) present different categories of students' answers to this kind of problems when solved in a DGS environment. They present an approach to show how the DGS allows students to move between conjecture and verifying the conjecture to enable them to produce deductive justifications in a dynamic geometry environment.

In their experimental study Erbaş and Yenmez (2011) explored the effects of using a dynamic geometry program with inquiry-based teaching methods on the sixth grade students' geometry achievements in a specific subject. The experimental group taught with a dynamic geometry program and inquiry-based teaching methods and the control group taught with a textbook-based direct instruction. According to achievement test score, which was administered as pre-test, post-test, and delayed post-test in both groups, the experimental group significantly improved their performance in geometry. Moreover, students in the experimental group displayed greater interest and motivation toward learning geometry when it is compared with control group.

The effective usage of a dynamic geometry program is crucial for mathematics education. Therefore, mathematics teachers should be familiar with these technologies. After taking part in a technology-based courses and learn technical skills to use their potential in application, the PSTs need experiences with technological tools in the field experience (Hixon & So, 2009).

## **2.7 Summary of the Related Literature**

Improvements in educational technology over the last twenty years lead by computer software assisted instruction have become widespread in educational



environments. Educational technologies have begun to be a significant part of the teaching and learning process in Turkey as well. The current elementary mathematics curriculum in Turkey emphasizes using technology effectively in teaching to provide students the opportunity for expressive mathematics teaching (MoNE, 2009). Kersaint (2007) claimed that the use of technology in education enables students to visualize mathematics, engage in active learning strategies, verify conjectures, have positive attitudes, and build confidence in their ability to do mathematics. Specifically, dynamic technology-supported instruction presents an opportunity to enhance mathematical reasoning. For instance, with the help of dynamic geometry software students are able to explore various conjectures by constructing geometrical shapes and making connections between them (MONE, 2009). The role of the teacher in the use of these technologies in the classroom is essential. In order to be an effective teacher, PSTs need to learn fundamental concepts, knowledge, skills, and attitudes for applying technology in educational settings (NETS•T, 2008). Therefore, teachers need to be trained how to use educational technology in their field of study. They should also be able to model appropriate uses for a variety of established and new applications of technology as tools to develop a deeper understanding of mathematics in varied contexts. However, the majority of pre-service teachers are unable to implement what they learn about educational technology and how that knowledge would be used in a real classroom context. In order to incorporate technology in mathematics teaching, teacher training programs should strengthen the PSTs' TPACK before they graduate.

Teacher educators are tasked to support teacher candidates in the effective use of technology in their teaching and they can provide courses and they should provide opportunities for teacher candidates to plan and practice teaching in field experience. The literature on TPACK development in teacher education reveals that providing PSTs opportunities to experience technology-based lesson implementation might improve them professionally. As stated in the previous section, the literature suggests that through field experience and reflection-on-action teachers have several opportunities to

develop themselves professionally such as putting theoretical knowledge of teaching into practice. Through experiences and reflective activities, PSTs improve their technology-based TPACK skills.

This study aims to utilize these theoretical frameworks for both sets of guidelines. The purpose of the study is not to choose and then defend a particular framework or set of guidelines; rather, it is to examine, implement and refine methodologies that support the development of TPACK with novice teachers in a field experience setting. More research is needed to provide the frameworks for professional development programs aimed at developing TPACK (Niess, 2006). The purpose of this study is 1) to examine the contribution made by field experiences and reflection-on-action processes to PSTs' TPACK levels in different teaching experiences specific to designing and preparing teaching aids; 2) To measure the extent of the changes and adaptations made by three PSTs in their TPACK through of the implementation of three technology-based lessons in a field experience; 3) To analyze PSTs' interpretations of their experiences with educational technology throughout the implementation of three lessons in a field experience.

To conclude, when it is taken into account that this study creates a learning environment in which PSTs have the opportunity to discuss on their own real classrooms practices and to learn by implementing technology-based lessons, and to prepare themselves for their future teaching career, this study contributes to the limited literature on TPACK studies in Turkey. While the new elementary mathematics curriculum requires that teachers use educational technology in their teaching, this experience might help them get ready for technology-based teaching environments. In the light of previous studies in teacher education, this study aimed to provide PSTs the opportunity to get ready for technology-based teaching and learning. To this end, the changes in PSTs' TPACK level as they implemented technology-based mathematics lessons in real classrooms and their interpretations about these implementations were investigated.

## **CHAPTER III**

### **METHODOLOGY**

This chapter describes the method of inquiry. The chapter starts with research questions, research design, context and participants, procedures, the data collection instruments, data analysis sections, role of the researcher then followed by addressing trustworthiness, credibility, ethics, and limitations.

#### **3.1 Restatement of the Purpose and Research Questions**

The current study had three main goals. First was to investigate the change in PSTs' TPACK levels based on the TPACK Levels Rubric within the context of their teaching practice. Second one was to explain the change and development in PSTs' TPACK during their field experiences. Third one was to identify interpretations of the three PST's experiences after designing and implementing three technology-based lessons. With this aim, the central research questions guiding this qualitative case study were the following questions:

1. What are PSTs TPACK levels in three different teaching implementations?
2. To what extent do PSTs develop their TPACK through the implementation of three technology-based lessons in a field experience?
3. How do PSTs interpret their experiences with educational technology through the implementation of three technology-based lessons in a field experience?

### **3.2 Design of the Study**

The design of the study is a case study. Case study is a bounded system (Creswell, 2007) and it aims to get in-depth information about the situation and participants (Merriam, 1998). To describe the case, this study particularly was interested in analysing the nature of multiple source of information. Data of the study was collected through four different sources; interviews, observation notes, PST's documents and videotape.

### **3.3. Context**

The context of the study was Elementary Mathematics Teacher Education (EME) Program and collaborative middle schools in field experience.

#### **3.3.1 Elementary Mathematics Teacher Education (EME) Program**

The setting for this study is the Middle East Technical University (METU) in Ankara, Turkey. This university is highly respected international research university, has been the leading university in Turkey in terms of strong international ties and the funds provided from research projects. The instructional language at METU is English. All of the students have to take English Proficiency Exam to prove that they have English language skills. There is optional one year Basic English Courses provided by METU to assist students in this Proficiency Exam. After passing English Proficiency Exam, students can start their field education in their department. The students selected as subjects for this study were enrolled in the Elementary Mathematics Teacher Education Program (EME). It is an undergraduate program under the Department of Elementary Education in Faculty of Education at METU. This four-year teacher education program aims to “raise teachers who have a strong background in theories about teaching and learning, disciplinary and content knowledge and practicum experience” (Middle East Technical University, General Catalog, 2010, p.406). Program “emphasize systematic

inquiry into teaching practices, integration of technology into instruction, innovative teaching methods and implementations, and communicative and self-help demands of teaching profession” (Middle East Technical University, General Catalog, 2010, p.406).

In the first two years of the EME program, students have to take mathematics courses from the Department of Mathematics (MATH), an introduction to education course, and courses related to English and Computer Applications. In the Computer Applications course, students expect to develop their mathematical content knowledge. In the last two years of the program, pedagogical courses and mathematics teaching courses, which aim to develop students’ pedagogical content knowledge, are given as compulsory courses. In total, students take nine mathematics courses, five pedagogy courses and ten courses related to elementary mathematics and science teaching courses. The students also have to take elective courses offered by different departments. Courses designed to support the PSTs development of technology based lesson plan were ELE 225 Measurement and Assessment, ELE 341 Methods of Teaching Mathematics I, ELE 342 Methods of Teaching Mathematics, ELE 329 Instructional Technology and Material Development, and ELE 430 Exploring Geometry with Dynamic Geometry Implementations. The participants of the study were elementary mathematics majors who had taken ELE 430 and were enrolled in ELE 435 (the course descriptions follow).

### **3.4 Participants**

The participants of the study were fourth year PSTs in the undergraduate program of Elementary Mathematics Education. The participants of the study were chosen by purposive sampling method to reach people who would provide rich information about the research question (Creswell, 2007; Given, 2008; Patton, 2002). To select information-rich cases the two interrelated benchmarks were taken into consideration. The first benchmark was PST’s should have completed the technology-based course.

The second benchmark was PSTs' enrollment into the School Experience course at the time of data collection.

ELE 430 – Exploring Geometry with Dynamic Geometry Applications (Spring 2011): Introduction to GeoGebra software with emphasis on technical and pedagogical skills needed to teach geometry in grades 6-8.

ELE 435 – School Experience (Fall 2012): Introduction to grade 6-8 learning environment through classroom observations, and the planning and implementation of a learning-center activity.

The syllabi of the courses were given in Appendix A1 and Appendix A2.

In 2010-2011 academic years second semester ELE 430 Exploring Geometry with Dynamic Geometry Applications course was offered in Elementary Mathematics Education Department and eight third-year students, eight fourth-year students and two graduate students enrolled into the ELE 430 course.

In 2011-2012 academic year, first semester ELE 435 School Experience course was offered in Elementary Mathematics Education Department. A total of eight PSTs had enrolled in the ELE 435 School Experience course, who had already taken ELE 430 course in previous term. Researcher asked eight students to participate in the study and six of them accepted. The data were collected with these six participants via interviews, technology-based lesson implementations, observations and documents. Researcher observed all of the teaching sessions and conducted all of the interviews. Three of the six participants were chosen to have required data from a cohort of six participants for the post hoc case study analysis. Before selecting subjects for the case study, a preliminary filtering process had been conducted. Via listening to the interview recordings and watching to the lesson implementation videos for all six a preliminary analysis of the data was conducted. Then researcher categorized the all six participants and reported three of the subjects selected for case study. The three of the participants were Meltem, Pelin, and Ali (pseudonyms). Meltem, exhibited an especially strong knowledge of technology, Pelin showed substantial change in the success of

implementation from the first to the third and Ali showed a strong technological knowledge during the study but claimed that technology was not a crucial teaching tool to teach mathematics. The detailed information about the subjects of the study was given in the next section.

### 3.4.1 Subjects of the Study

These three participants Meltem, Pelin, and Ali were graduated from Anatolian Teacher Training High School. In addition to high school curriculum, Anatolian Teacher Training High School includes pedagogical courses and leads them to be a teacher. They all have also tutoring experiences for students from different grade levels in elementary and high school. Table 4 presents pseudonym name of participants, their gender, C.GPA, final grades of ELE 430 and ELE 435 course and the school type that they were teaching at collaborating schools.

Table 3.1 Background information of participants

| Pseudonyms | Gender | C. GPA<br>(out of 4) | Grade<br>ELE 430 | Grade<br>ELE 435 | School Type |
|------------|--------|----------------------|------------------|------------------|-------------|
| Ali        | Male   | 3.00                 | AA               | AA               | Private     |
| Pelin      | Female | 3.36                 | AA               | AA               | Public      |
| Meltem     | Female | 3.49                 | AA               | AA               | Public      |

Specific background information for each of these three pre-service teachers follows.

Meltem was the first subject of the post hoc case study, since she exhibited an especially strong knowledge of technology during the study. Before university education she didn't interested in any kind of technology at all. After she took technology-based courses she noticed her ability to use educational technology in teaching. Meltem constructed all GeoGebra activities by herself. In her opinion educational technology is not just a tool to make the lesson interesting; it is a teaching tool that gives teachers chance to have students reasoning about the mathematical proofs. She had no teaching

experience in real classroom context previously. She emphasizes the importance of the questioning as a teaching method while using educational technology in mathematics teaching. In addition to Elementary Mathematics Education major, Meltem had been pursuing a minor degree in pure mathematics. Meltem had no experiences in university entrance examination preparation centers as a tutor. Before the study, Meltem had been tutoring for her brother and cousins in all grade levels from elementary to university grades to support them in their math courses. Meltem worked as a volunteer in a (Kardelen) project prepared by Association of Mathematicians (Matematikçiler Derneği) and The Association for Supporting Contemporary Life (Çağdaş Yaşamı Destekleme Derneği). In these projects she worked as a tutor for two students who have low mathematics grades in their schools.

Pelin was the second subject of the post hoc case study, since she showed substantial change in the success of technology-based lesson implementation from the first to the third based on the TPACK levels Rubric. In her opinion, educational technology helps students make abstract mathematical concepts concrete in their mind. Therefore pre-service teachers should have the basic techno-pedagogical knowledge to use educational technology in their mathematics teaching effectively. She has a special interest for the technology in her personal life. Pelin was pursuing Elementary Mathematics Education major. Pelin was a private tutor for 5th to 8th grade level students from her freshman year to senior year at the university. Pelin worked in examination preparation centers [dershane] as a teacher to support for 6th, 7th and 8th grade level students from 2010 to 2011 to assist them in national examinations. In addition, she worked as a tutor in the community service course. She was a mathematics tutor for a hearing-impaired student in the METU Without Barriers Student Club.

Ali was the third subject of the post hoc case study, since he claimed that teacher don't need to use educational technology in every single mathematics subject to teach, since some subjects are more appropriate to teach via physical manipulative. (For example place value should be taught via ten blocks). In his opinion, using technology in



teaching brings some additional responsibilities for the teachers. Ali was interested in technology in general. Ali worked in the METU Community and Science Center as a tutor for middle school students. To enhance middle school student's academic achievement in their school, he implemented special mathematics lesson. Ali was a tutor for two high school students to support them in their math courses. Ali didn't work in examination preparation centers. A small stipend was paid to all six of the volunteer pre-service teachers in the present study.

### **3.4.2 The Description of ELE 430 Course**

ELE 430 Exploring Geometry with Dynamic Geometry Applications course was designed and implemented a specific technology course for elementary mathematics education at undergraduate level in Elementary Mathematics Teacher Education Department of METU, in 2010-2011 academic year second semester.

This course was an introduction to mathematical applications of dynamic geometry. In this course, PSTs learned how to use dynamic geometry software applications to engage in mathematics investigations in elementary mathematics content and with special emphasis on how to organize pedagogical techniques to integrate technology mathematics lesson and enhance mathematics teaching and learning in grades 6-8. This course was a lab-based course and all of the PSTs had their own computer with dynamic geometry. During the course, specific mathematics topics were explored two times a week 2 hours each with PSTs during a semester long. PSTs had a chance to explore their conjectures and validate their mathematical reasoning through multiple representations including graphical and numerical analyses. PSTs' conjectures regarding the notion of parallel lines, geometric shapes, transformations, trigonometry and developing a conceptual understanding of proofs of geometric theorems thoroughly discussed. In each class session, at least three GeoGebra activities related the topic were constructed.

In particular ways to facilitate mathematical reasoning and conjecturing remained the primary focus of the activities. During the semester, the activities were guided by the instructor, or students were given time to complete the activity by themselves. It was aimed with these classroom activities help PSTs learn how to use dynamic geometry applications to engage in mathematics investigations, and organize pedagogical demonstrations. Since an activity for proving or solving a geometry concept could be completed in different ways, the students came up with different methods in the classroom and they were asked to present their methods in the classroom.

In this course PSTs had assignments that required; homework write-ups, homework readings and their reflection papers, final project (includes lesson plans, GeoGebra activities, activity sheets and answer sheets) and micro- teaching of final project. For detailed information see Table 3.1.

Table 3.2 Course assignments of ELE 430

| Time                                                               | Assignment                                           | Aim of the Assignment                                                                                                                                                                                                                                                                                                                                                                             | Evaluation                                                                                                                                                                                                                                                                                                                                                                     |
|--------------------------------------------------------------------|------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Each class session                                                 | Exploration of specific geometry topics via GeoGebra | Explore conjectures and validate their mathematical reasoning through multiple representations including graphical and numerical analyses                                                                                                                                                                                                                                                         | PSTs saved their lesson activities and prepared a portfolio                                                                                                                                                                                                                                                                                                                    |
| 5 weeks                                                            | 3 groups Write-Up Problems                           | Challenge PST's technical knowledge                                                                                                                                                                                                                                                                                                                                                               | Selects and implements relevant concepts and procedures/strategies<br>Considers all constraints of the problem situation                                                                                                                                                                                                                                                       |
| Two times (4 <sup>th</sup> and 8 <sup>th</sup> week of the course) | Readings articles and writing reflection papers      | Give PSTs a broader perspectives about how to use technology and have evidence about their development                                                                                                                                                                                                                                                                                            | Evidence of deep reaction to consider the impact or implications of these ideas on the teaching and learning of mathematics<br>Evidence that PSTs are grappling with these ideas to understand their relevance to them personally<br>Evidence that the ideas have stretched PSTs' thinking                                                                                     |
| At the end of the course                                           | Final Project                                        | Choosing different topics from grades 6-8 and creating 3 lesson plans<br>Project help school children to discover, explore, or comprehend a mathematical concept (or a set of concepts)<br>Paragraph long description of how to use it in the mathematics classes.<br>Students' worksheet.<br>Student's anticipated questions for the activity and students' possible answers for this questions. | Correctness of constructions and mathematical ideas.<br>Instructional/educational value and suitability for use in real classroom.<br>Visual quality; the figures and other elements on the screen should be clear for intended audience<br>The revised projects were submitted at the end of the semester in order to use them in their future mathematics teaching practice. |
| End of the Semester                                                | Micro Teaching                                       | PSTs present their projects to the peers                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                |

Out-of class-assignments of this course were; write ups, readings and their reaction papers, final project (includes lesson plans, GeoGebra activities, activity sheets and answer sheets) and micro-teaching. In this section detailed information for each assignment was provided.

First out-of class-assignment used in this course was write up questions. With this assignment it is aimed to provide PSTs a chance to construct, observe and solve the mathematical problem and challenges their conceptual knowledge in mathematics. By write-up questions it is aimed to challenge PSTs' conceptual understanding in mathematics. If PSTs have problems while creating these activities, they also discussed in the classroom. By this way it is aimed to obtain information about how do pre-service teachers come to understand the use of dynamic geometry for solving problems, for reasoning, and for communicating about significant mathematics as well. Each two or three week students were given 3 write-ups problems where students would create a GeoGebra activities.

Second out-of class-assignment of this course was reflection paper. Throughout the course period two times, in the 4<sup>th</sup> and 8<sup>th</sup> week of the course, one article was given to the PSTs in order to give them broader perspectives in Dynamic Geometry environment. By reading these articles, PSTs had a chance to see a concrete example of how dynamic geometry software can be used effectively in mathematics classroom. The PSTs were asked to give a brief summary of the article and their thoughts about the article with the specific explanation of the points that they agree or disagree with. PSTs wrote their paper as a teacher whether or how the ELE 430 course is likely to influence their practice and added their experiences during the course.

Third out-of class-assignment of this course was developing creative GeoGebra projects. At the end of the course PSTs were asked to create a project. The final project should help school children to discover, explore, or comprehend a concept (or a set of concepts) which are directed toward a deeper level of understanding of these concepts on the part of the students. For this aim PSTs prepared Geogebra

demonstrations/explorations choosing different topics (or a series of related topics) in geometry that is/are in line with the national curriculum from grades 6-8. PSTs created GeoGebra activities together with lesson plans and they prepared a worksheet for each activity. Required students to work with a worksheet. Their anticipated questions for the activity and students possible answers for this questions. A paragraph long description of how to use it in the mathematics classes. It is expected this final projects would enhance the learning of geometrical concepts through exploratory activities to build mathematical intuition, and as tools to solve problems.

Fourth out-of class-assignment of this course was Micro Teaching. While microteaching, PSTs presented their projects and explained how they would use the activities in the mathematics classrooms. Then the instructor, teaching assistant and their colleagues provided feedback. Based on these feedbacks, PSTs revised the activities and lesson plans. The revised projects were submitted to the NET-ClassR at the end of the semester in order to use them in their future teaching practice. NET-ClassR is a learning management system developed by METU Informatics Institute in 1997. METU Academicians use NET-ClassR to manage their courses in an online environment. The major features of NET-ClassR were lecture notes, syllabus, forum, e-mail, online exam, announcements, assignments, links and gradebook etc. PSTs uploaded their completed assignments to NET-ClassR using file transfer programs and had a chance to share their portfolios with each other.

In ELE 430 course the role of the instructor was to guide students through experiences to complete the lesson activity and course assignments, and act as a facilitator and supporter of their learning. She tried to sustain and support inquiry-based teaching and create a positive learning environment to lead PSTs participate in class discussions and learning opportunities and work with their classmates. During the activities, instructor reflect on the activity via asking PSTs pedagogical questions and encourage them to answer and ask new questions about the activity. There were two groups of pedagogical questions. The first group of questions were open-ended and

asked PSTs to make reasoning about the GeoGebra activity. Via these questions, the instructor elicited PSTs' thinking and had their opinion about the activity. After they completed the task together, PSTs answer the questions posed them to discuss how to organize pedagogical techniques to integrate technology mathematics lesson and provide information about their thinking. Some example of the first group questions were; how can you construct dynamic representation of that mathematics concept via GeoGebra? Why is it important to construct this object first?, Here is an idea that might help you to construct this sketch?, If you explain how you construct, maybe we can help you figure out where you are making a mistake?, Is there any other way to construct this activity?, What would happen if...? etc.

After finishing construction of GeoGebra activity, instructor asked second group questions. These questions were open-ended questions to have PSTs make reasoning about the implementation of the geometrical activity in real classroom environment. Via these questions instructor elicit PSTs' thinking and having their opinion about the implementation of the activity. PSTs answered the questions posed to them and provided information about their thinking. Some examples of second group questions were; how might this activity be useful for you as a teacher with your students?, What kind of "what if" questions can you asks to students on this task to facilitate their understading?, Do you think the use of this sketch can somehow change the learning environment?, Which difficulties do you think can be encountered when conducting this activity?

### **3.4.3 Role of the Researcher**

Patton, (2002) stated that researcher is a part of qualitative data since it is an interviewer or observer; therefore it should be provided thick description about researchers' role and bias in data collection and analysis process. In order to ensure the quality of the data it is important to provide information about researchers' bias (Creswell, 2007).

Researcher has five years of teaching experience as a mathematics teacher in a middle school from the year 2003 to 2007. She has a master degree in Educational Sciences. Currently, she is a research assistant and doctorate student in the same department with the participants. She had close contact with PSTs during her assistantship and she was in the continuous contact with the participants from the beginning to the end of the study.

During her PhD education, she was interested in educational technology in mathematics education and teacher training. She completed courses related to these two issues. She believes that 21<sup>th</sup> century mathematics teacher should use technological devices and content specific software to design technology-based mathematics lessons. She also believes that field experience course is an opportunity for PSTs to use their knowledge that they gained undergraduate courses in practice. Reflective thinking activities, before and after each practice, are also helpful to improve their teaching qualities.

In 2010-2011 academic year fall semester, six PSTs implemented three technology-based mathematic lessons. The researcher observed and videotaped these lesson implementations. She conducted an interview with PSTs before and after each lesson implementation with each participant individually. The three subjects selected for case study and reported in this study. In this process researcher acted as facilitator. Researcher supported PSTs to regulate teaching environment and solve the probable technical problems during lesson implementations. In data collection and analysis procedure she tried to be objective to eliminate researcher bias. She avoided using her personal ideas about the usage of educational technology in mathematics teaching. She recorded all of the interviews and lesson implementations to decrease the researcher bias. To have PSTs inform about their strengths and weaknesses as a teacher in technology-based lesson, she conducted reflection-on-action process with PSTs. In this process she helped PSTs to bridge theory and practice. The detailed results of this experience are reported in this study.

### **3.5 Data Collection Process**

Interview and observation were main data collection tools for this study to have information about PSTs' views, approaches and practices of TPACK.

#### **3.5.1 Data Sources**

The data for this study were collected in 2011-2012 academic year fall semester. Entire data collection process took about three months. Time schedule for data collection see the Table 3.2



Table 3.3 Time schedule for data collection

| Timing                                | Data Collection Method          | To Answer RQ                                                                                                                     |
|---------------------------------------|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Beginning of the study                | Initial Interview               | PSTs' general opinions about educational technology in mathematics education (RQ 1, 2)                                           |
| Before three lessons' implementations | Pre-Interviews                  | Evaluate the lesson plan and GeoGebra activity and make a comparison with previous lessons in terms of change in TPACK (RQ 1, 2) |
| During three lesson implementations   | Video recordings & Observations | To triangulate data and to recognize the techno-pedagogical skills used by PST during the lesson (RQ 1, 2)                       |
| After three lesson Implementations    | Post-Interviews                 | Reflect on the lesson implementations and compare with the previous lessons (RQ 1, 2)                                            |
| End of the study                      | Last Interview                  | To have information about PSTs interpretations of the experience and their self-evaluation of TPACK progress (RQ, 3)             |

The dates of the interviews and implementations presented in the Table 3.4

Table 3.4 The dates of the interviews and implementations

| PST    | Date I   | Date II  | Date III | Date IV  | Date V   | Date VI  | Date VII | Date VIII | Date IX  | Date X   | Date XI  |
|--------|----------|----------|----------|----------|----------|----------|----------|-----------|----------|----------|----------|
| Meltem | 22/11/11 | 06/12/11 | 09/12/11 | 09/12/11 | 23/12/11 | 23/12/11 | 03/01/12 | 30/12/11  | 30/12/11 | 03/01/12 | 02/01/12 |
| Pelin  | 15/11/11 | 09/12/11 | 09/12/11 | 13/12/11 | 13/12/11 | 14/12/11 | 26/12/11 | 28/12/11  | 29/12/11 | 02/01/12 | 02/01/12 |
| Ali    | 09/11/11 | 12/12/11 | 13/12/11 | 14/12/11 | 23/12/11 | 23/12/11 | 05/01/12 | 09/01/12  | 10/01/12 | 13/01/12 | 17/01/12 |

This study was particularly interested in analyzing the nature of multiple source of information to describe the phenomena. The following section explains in detail the major data sources of the study.

#### **3.5.1.1 Interviews**

There were four types of semi-structured interviews in this study. These were the initial interview, last interview, pre-interview and post interview. The duration of the initial and last interview was approximately one hour, while, the pre-interview and post interview was half an hour.

A pilot study was utilized for each interview protocol to increase internal validity and feasibility of the study. To reflection-on-practice process open-ended questions were prepared based on the related studies. The focus of the interview questions were to examine the change and adoptions in PSTs' technology integration into mathematics education. The technology-based activity was required to be aligned with the lesson objective. In the questions PSTs were asked to assess the appropriateness of technology-based teaching activities in their lesson design and tried to have PSTs noticed the strength and weaknesses of the lesson. After preparing interview questions, the appropriateness of them was evaluated by two experts, who were faculty members experienced in TPACK studies, individually. Based on the expert opinions the interview questions were reorganized. Then clarity of the interview questions was piloted with a PST. According to PSTs opinions some questions were clarified, repetitive questions excluded from the protocol and the order of the questions redesigned. After these revisions final version of the interview protocols were formed.

Face-to-face semi-structured eight interview protocols were conducted with each participant individually in the study. The interview dates were arranged in consistent with PST's weekly schedule. Interviews with PSTs was conducted both in the department of elementary education and in practice schools that was natural and familiar

to the participants and in a separate room provided by the administrations. Interviews conducted in a conversational method and tape recorded with participants' permission. Researcher asked questions and waited for a clear answer for each question from each participant. When it was necessary, questions repeated or explained to the interviewee. Additionally during these interviews, PSTs shared their opinion about how much percent they reach the course objectives, what kind of behaviors that they want to improve to use dynamic geometry program effectively and an explanation about their future teaching plan via dynamic geometry. Interviews were audio-recorded and the duration of the semi-structured interviews were 30 minutes.

#### **3.5.1.1.1 Initial Interview**

Initial interviews were conducted with the participants to have information about their demography and their education. Based on their previous knowledge and experiences their thoughts about educational technology in math teaching before the study were also asked in initial interview. Some of the questions in the initial interview were given below; the full version of the initial interview protocol was presented in the Appendix B1.

##### *Content of the Initial Interview Protocol*

- Do you like using technology in general?
- Which pedagogical content courses did you enrolled in?
- Which TPACK content courses did you enrolled in?
- Which educational technology can you use in mathematics education?
- How long have they been using that technology? For what purpose this program has been created?
- What is he advantages or disadvantages of educational technology in mathematics classroom?

- What is your opinion about the role of technology in mathematics teaching?
- What is your expectation from the current teaching practice?
- What is your personal opinion about preparation for an ideal technology-based lesson?

#### **3.5.1.1.2 Last Interview**

Last interviews were conducted with the participants to have information about their self-evaluation of the implementations based on their experiences. Their thoughts about educational technology in math teaching after the study were also asked in last interview. The content of the questions in the last interview are given at below; the full version of the last interview protocol was presented in the Appendix B2.

##### *Content of the Last Interview Protocol*

- What is your general opinion about the role of technology in mathematics teaching?
- What is the advantage of using educational technology in teaching?
- What is the disadvantage of using educational technology in teaching?
- What is your strength and weaknesses in using educational technology in math teaching?
- Is this implementation process contributed to your teacher knowledge, how?
- Can you evaluate yourself in terms of educational technology usage in this process?
- Do you feel ready to use GeoGebra program in your future mathematics classroom? Why?
- Do you need additional courses to improve your TPACK in teacher training program?
- Can you evaluate the quality of the technology-based courses that you took in

terms of contribution of their professional life?

- What are the essential knowledges that a teachers need to use educational technology in mathematics lesson effectively?
- Do you have any suggestions for policy makers to integrate technology in math education?
- What is your professional plan for your future teaching activities?

### **3.5.1.1.3 Pre-Interview Before Each Lesson Implementation**

Participants were interviewed before each teaching sessions to have information about their expectation about the lesson implementation. In the interviews, PSTs shared information about the detailes of the technology based activity; starting, middle, closing, extension (optional) and assessment. They explained teaching procedure, which mathematical concept they would teach via technology, what kind of pedagogical (inquiry) questions they were planning to ask in the lesson. They shared their plan about how they would support students' mathematical understanding and their expectations related to students reflections to the technological activity. Finally, participants gave technical information about the technological activity. The content of the questions in the pre-interview were given below; the full version of the pre-interview protocol was presented in the Appendix B3.

#### *Content of the Pre-Interview Protocol*

- Which educational technology will you use in this lesson?
- In which grade level you are going to implement your lesson?
- This lesson will be implemented in classroom or computer lab environment?  
Why?
- Can you give information about the technological sources in the classroom?
- What is the source of technological activity? Did you construct it yourself or did

you find it from internet/friends or?

- Have you ever been in this class previously for observation or lesson implementation?
- Which mathematical subject are you going to teach?
- Why did you choose this specific content to teach with educational technology?
- Can you explain the teaching methods that you will use in the lesson?
- Can you explain the purpose of the activity that you will use in the lesson?
- Can you explain the role of the technology in class?
- Can you explain the role of the PSTs in class?
- Can you explain the explanation of the role of the students in class?
- Do you have any concern about the usage of technology in teaching mathematics for this lesson?
- Are you ready for the lesson? Why (not)?

#### **3.5.1.1.4 Post-Interview After Each Lesson Implementation**

Participants were interviewed after each teaching sessions to have information about their self-evaluation about the lesson implementation. PST shared their opinion about the implementation of technological activity whether it is implemented as it planned. They explained teaching procedure includes the actions and questions that they asked during the class. They evaluated students' performance. They were asked to give information about their satisfaction about their teaching, handling with drawbacks, classroom and time management. The content of the questions in the post-interview were given below; the full version of the post interview protocol was presented in the Appendix B4.

##### *Content of the Post-Interview Protocol*

- Can you assess the compatibility of the technological resources in classroom

required for the implementation of your technology-based lesson?

- What was the strength and weaknesses of the lesson implementation?
- What is your opinion about your self-confidence during the technology based teaching activities?
- What are the issues that you want to improve for the next lesson implementation?
- What are the issues that you want to pay more attention related to the use of technology for the next lesson implementation?
- Was there any unexpected events related to educational technology in that lesson?
- What did you do to deal with this unexpected event?
- What was the students' reaction to the use of technology in that lesson?
- What was the advantage of the usage of educational technology to have students reach the lesson objectives in that lesson?
- Can you evaluate your performance in the lesson implementation?
- Did you have any classroom management and time management problem in that lesson? Can you explain?
- What were the easiest and the most difficult part of the lesson?
- What were the disadvantages of using educational technology in teaching for that lesson?

For the second and third implementation interviews, the PSTs were not only asked these questions, but also they were asked to make a comparison between previous implementations in terms of their self-improvement in educational technology usage as a teacher. The examples of these questions were given below.

- Is there any difference between previous and this implementation in terms of aim of the educational technology, teaching methods and questions being asked?



- In which lesson, technology usage was more essential than the other? Why?
- Is there any difference between comfortable feeling
- Is there any difference between previous and this implementation in terms of self-confidence?
- Does having these experiences affect your chosen topic and teaching? How?

### **3.5.1.2 Observations Notes and Video-Tapes**

In addition to the interview, conducting an observation is requisite to validate the interviewees' response and go into the deep analysis of the data. The researcher was nonparticipant observer in the study. She didn't engage in the lesson. She sits in the corner of the classroom and observed the lesson by focusing on PSTs and their interaction with elementary students. She tried to observe the change in PSTs' TPACK and avoided from affecting participants' activities and behaviors.

Observation protocol was divided into two parts for descriptive and reflective field note (Creswell, 2007). First part of the observation protocol was planned to describe the environment of the lesson implementation (classroom or lab environment). Descriptive field notes were to record the identification of technology based activities of PSTs without personal ideas or evaluations. This part included description of the lesson implementation (the descriptions of technology-based activities, the purpose of the activity, the questions that PSTs asked to the students and their observable reactions to these questions, the problems that occur during the class time related to technology, PSTs' coping behaviours with these problems). For example the purpose of the technology usage might be the visualisation of a mathematical concept, demonstrating a relationship between two geometrical concepts in a dynamic way by moving the slider, modelling a mathematical problem, giving hints to help students solve the problem etc. There were also blanks for date and the duration of the lesson. Second part of the observation protocol was planned to record reflective field notes, which includes

personal reflections and evaluation of the PSTs' TPACK performance. Then a technology based lesson implementation was conducted by one of the participants of the study and usability of the protocol was piloted in a technology-based classroom. Then necessary revisions were accomplished. After these revisions final versions of the observation protocols were formed.

Since interviewees may reflect their selective perceptions (Patton, 2002) in the interview, this data should be supported with another data sources. In addition to interviews, in the present study observation method was used to collect data. The aim of the observations was to make an interpretation about change in PSTs' TPACK. Therefore, conducting observations beside the interview seem crucial in means of going deep into the setting, activities and practices PSTs engaged in. The observation protocol allowed a detailed description of the classroom behavior. It addressed how PSTs engage students in a technology-based activity. The observation protocol helped the researcher focus on the particular behavior of PSTs. How professionally PSTs implemented their lesson plan. When and how PSTs used GeoGebra activity in the lesson? How PSTs guided students to use technology? What did PST actually do during the second and third lesson implementation different than previous implementations? Is there any observed evidence of change in their TPACK throughout the study. After preparing the observation protocol, the expert opinion was taken, experienced in qualitative study and TPACK, to ensure 'peer review'. Then, the necessary revisions conducted in the protocol. The lesson implementations were also video recorded to triangulate the data for the trustworthiness of the study. The location of the camera was near to the observer to view the technology based activities conducted by PSTs and the back side of the students. In Ali's school, the video recording was not allowed in the school administration therefore a second observer was employed in one of his lesson implementations to enhance the validity and reliability considerations (Fraenkel & Wallen, 2011). The second observer was the peer of the participants. Second observer was a 4<sup>th</sup> grade undergraduate student at the Elementary Mathematics Education. Three

observations were conducted for each participant. The duration of each observation was one or two lesson hours. Observation protocol was especially helpful for Ali's implementations, since his lesson implementations were not videotaped, it was observed with this protocol. The observation protocol was coded with another researcher in one of the Ali's lesson implementation. The observation protocol is presented in the Appendix C.

Lesson implementations were videotaped except Ali. Since private school policy, in Ali's collaborative school didn't allow us to videotape lesson implementation, instead one of his implementations observed by second observer.

### **3.5.1.3 Documentation**

In addition to main data sources PSTs' lesson plans, reflection paper prepared for ELE 435 and ELE 420 courses and students' reflection papers related to PSTs' implemented lesson were reviewed in the study. First additional data source was lesson plan. PSTs were required to prepare lesson plans for each technology based lesson implementation. Each PST developed three lesson plans based on national curricula in different mathematics topics. It was required from PSTs to prepare three detailed lesson plans with an activity to teach a particular mathematics topic by using GeoGebra software. Lesson plans included procedure, extension and assessment parts. A lesson plan template provided PSTs to have them prepare lesson plan in the same way and be sure that necessary component included. Lesson plan template consists of six main components; lesson objectives, prerequisite students knowledge, sequencing of the lesson (starting, middle, closing, extension (optional), assessment), activity sheet, anticipated students' answer (optional), technical information about how to construct GeoGebra activity. Activity sheet was for students and it included the description of the task and the steps that they follow while doing the activity. Secondly, reflection paper prepared by PSTs was used. PSTs were required to write reflection papers for ELE 435

and ELE 420 courses based on their experiences in teaching practice. Although this study was not a part of these courses if participants wrote their perceptions about their implementation in the scope of this study, these papers used as an additional data sources. Third additional data source was student reflection paper. Collaborative school students were required to write a reflection paper after the lesson implementation related to PSTs' performance and their experiences with technology. By the help of reflection papers, the pre-service teachers' thoughts about the lesson, students' solving strategies, their difficulties, and the influence of problem solving and modeling course on pre-service teachers' knowledge of problem solving strategy is examined. At the end of the lesson implementation if there is still time, students requested to write their reflections to the technology based lesson based on the reflective questions. The questions for this paper were;

- What have you learned today's lesson? Explain briefly?
- What do you think about the use of technological tool while learning this geometric issue? Explain your reasons.
- In which part of the lesson you enjoyed?
- In which part of the lesson you bored?
- How do you evaluate your performance in class discussion? What was the most difficult part for you? If you give yourself a score out of 10 what would be this score?
- Is there anything that you want to add related to this lesson?

If lesson implemented in computer lab a question was added to have students' preferences being in the computer lab and classroom while working GeoGebra activity. The added question is; "Do you prefer being in the classroom instead of being in the computer lab while working with GeoGebra file?"

### **3.5.2 Trustworthiness of the Study**

Trustworthiness is the main indicator for the quality of the study. Valid interpretation of the collected data, the “worth paying attention to the findings” (Lincoln & Guba, 1985, p.290), satisfying the expectation of the readers related to study results, is available with the highlighting trustworthiness of the study. Trustworthiness includes credibility (internal validity), transferability (external validity), dependability (reliability), and conformability (objectivity). These were enhanced through the strategies detailed below.

First indicator of trustworthiness was credibility. Credibility is the correspondence of internal validity in quantitative studies. Credibility deals with the questions of “how research findings match reality?” (Merriam, 1998, p. 213). Researcher should avoid from biases while interpreting the qualitative data. The ways to credible interpretation of the data is viable with the triangulation (data triangulation, investigator triangulation, theory triangulation, and methodological triangulation), prolonged involvement, member checks, peer examination, negative case analysis, debriefing sessions, thick description, and examination of other research (Merriam, 2009; Miles & Huberman, 1994; Patton, 2002). In this study triangulation, peer review, prolonged involvement, peer examination, thick description, and examination of other research techniques were used to deal with credibility. Data triangulation strategies were used to enhance the credibility of the study (Patton, 2002). To address the research questions multiple sources of data, observation notes, video records, interviews and documentations (lesson plans, reflection papers) were reviewed. PSTs’ interpretations to technology based lesson experiences clarified from different data sources. Some of the interpretations that PSTs stated in the interview were already observed in the lesson implementations. For example the themes motivation, tool, teacher role, classroom management, time management and implementation were both observed and stated by PSTs during the

interviews. This shows how the qualitative data from these two sources is supporting each other.

PSTs write about some of the interpretations in their reflections papers, as well. PSTs' change in TPACK described from different data sources. For example to evaluate a lesson implementation first their lesson plan were examined then two interviews were conducted related to lesson plan and lesson implementation. Lesson implementation was both observed and video recorded. All data sources were used to describe lesson and find evidences related to change in TPACK. Second strategy used for credibility was peer review; researcher collaborated with an associate professor, experienced with qualitative research and mathematics teacher's TPACK studies from the USA. She was a devil's advocate (Lincoln & Guba, 1985) of the study. Researchers met with professor at least once a week and discuss the analysis of the study. Via this way, the accuracy of data analysis was checked. Lesson descriptions, evaluations and interview transcripts were reviewed by associate professor. Then she asked questions to keep the researcher objective (Creswell, 2007) about method of analysis, meanings of explanations related to PSTs interpretations and evidences of change in TPACK. Professor listened the researcher ideas and feelings about the study. Third strategy used for credibility was prolonged involvement of the participants. Before the study participants of the study had already been in the schools as a trainee teacher for two months. In the content of ELE 430 course, they observed teaching and learning activities of teachers. PSTs prepared learning activities for students and implemented. They wrote reports related to a day of teacher, a day of a students, school-family cooperation etc. As stated in researcher role, researcher had a close contact with PSTs before the study. She was in the continuous contact with the participants from the beginning to the end of the study.

Second indicator of trustworthiness was transferability. Transferability is the correspondence of external validity in quantitative studies. In one hand, researcher's main concern is not the generalization of the results in qualitative studies; on the other hand, transferability deals with the questions of "to which context we can generalize the

research findings?” Researcher provides detailed information about the study in order to enable reader to transfer information to other settings with the help common characteristics that they were used to (Cresswell, 2007). Therefore the reader can compare the study with others. In qualitative studies, researcher should provide thick description of a study to verify the repeatability of the study by this way other researchers can be able to follow same procedures to repeat the study. To establish rich and thick description in present study, researcher firstly gave detailed information about technology-based course, and then she presented participants in terms of their demographical, personal and academic characteristics. Finally, each lesson implementations were described in detail.

Third indicator of trustworthiness was dependability. Dependability is the correspondence of reliability in quantitative studies. The aim of the dependability is minimize the biases of the researcher and possible errors especially in data collection and analysis process in the study. Dependability deals with the questions of “how researcher can repeat the study?” It is provided detailed information about the data collection and implementation process of the study, to help researchers to replicate the study. For this aim, firstly researcher had a notebook and wrote daily journals about the data collection and analysis process of the study. The date of the interviews and lesson implementations were recorded. Participants’ demographic information and researchers’ personal opinions about them were noted. The problems that occur during data collection and analysis process and the ways to handle them were also recorded in case of necessity in data analysis process. Secondly, interviews were audio taped and transcribed to have the raw data. Thirdly, lesson implementations were videotaped to refrain from missing data. Video records were watched number of times during the description of lesson implementations and time stamps were provided for dialog between students-teacher and students-students obtained from video records. Video records were also used to objective evaluation of PSTs TPACK. It is stated in data analysis process that inter-rater reliability was provided to analyze interview data for

consistent results. Last interviews were coded, by the researcher, and second coder individually. They had a discussion on the themes of the data and get an agreement on it. Inter-rater reliability was calculated. The second coder was an associate professor in USA and experienced in qualitative researches. In addition, the observation of Ali's lesson implementation verified with second coder. The second coder was a senior student in the same class with Ali.

Fourth indicator of trustworthiness was conformability. Conformability is the correspondence of objectivity in quantitative studies. Conformability deals with the questions of how objectively the study findings were supported by the data (Lincoln & Guba, 1985). Therefore, the aim of the conformability is providing information about objectivity of the instruments that used in data collection and analysis process. Researchers should be sure that the findings are the result of the participants' experiences and opinions not the characteristics and preferences of their own (Shenton, 2004). In qualitative studies, reader should agree the conclusion of the study. They shouldn't be able to generate a counter argument for findings (Carcary, 2009). In present qualitative study, to address third research question was the interpretations of participants to the technology-based lessons implementations were analyzed based on their expressions within the context of field experience. Researcher interpreted the meaning from data through a coding process. In this process, researcher looked for messages that PSTs wanted to give. In this study to reduce the effect of researcher bias, role of the researcher were described in detail. Demographic and personal characteristics of researcher were explained. The information about researcher predispositions related to educational technology was given. The validity of the data collection and data analysis tools was audited. To address second research question, which was the change in PSTs' TPACK was evaluated based on the TPACK levels rubric developed by Lyublinskaya and Tournaki (2011). The validity of the rubric were investigated and shared with the audience under the separate title of Validity of the TPACK levels rubric developed by Lyublinskaya and Tournaki (2011).



### **3.6 Data Analysis**

The data were analyzed through the qualitative methods. The main data sources of this study were; interview transcribes, videotaped lesson implementations, observation notes and documents (lesson plan, reflection papers). In this part of the study data analysis of the study was explained.

#### **3.6.1 Interview Analysis**

One of the main data sources of this study was interview. In order to analyse and interpret the interview data, inductive process of open coding method was used. The interviews were transcribed and translated into English by the researcher in order to collaborate with an associate professor experienced with qualitative research and analysis. According to Marshall and Rossman (2011) the analytic procedure follow the sequence of organizing the data, generating categories, themes and patterns, coding the data, testing the emergent understandings, searching for alternative explanations and writing report. From each transcript, significant phrases and sentences directly related to the interview questions were identified. Similar phrases were identified and appropriative themes were extracted from the data. While analyzing the data, associate professor, reviewed the data, validated the emerging themes and collaborated in the assignment of categories. At the beginning, the researcher and the coder studied independently to understand the emerging codes. After this open coding stage the researcher and coder studied together for the agreement of the emerging codes. Disagreements were solved by discussions on the interpretations of the answers of participants. Then they decided on the main categories that would frame the implementing technology based mathematics lessons. Sorting the theme items into distinct categories followed this analysis.

As stated data collection section there were four types of interview in this study. The initial interview was used in the presentation of participants to give information

about PSTs' demography, previous knowledge and experiences with educational technology. Pre-interviews were used in lesson description parts to explain PSTs expectations about the lesson implementations before the lesson. Post-interviews were also used in lesson description parts to explain PSTs self-evaluation about the lesson implementations after the lesson. The explanation of teaching procedure, whether the lesson was implemented as it planned, the actions they did and questions that they asked during the class were evaluated from the participants' point of view.

Last interview transcribe was used to answer to third research question. The third research question was, *how do PSTs interpret their experiences with educational technology through of the implementation of three technology-based lessons in a field experience?* To analyze the data, the researcher focuses was on the assist in implementation guideline found in the SITI Model. The purpose of the final interview questions was to promote and document reflection of PSTs on their experiences in real classroom context and their self-evaluation of the implementations. After PSTs had developed and implemented their technology-based lesson plans in actual classrooms, an interview was conducted. The purpose of the interview questions was to promote and document reflection on their experience. The average 50-minute interviews were transcribed and translated into English by the researcher in order to collaborate with an associate professor experienced with qualitative research and analysis. From each transcript, significant sentences directly related to the interview questions were identified. For example, the 18th question was about time: Because of using educational technology in your teaching, did you have any problems in terms of time management? A total of 24 items emerged and were numbered as they arose. Sorting the theme items into three distinct categories followed this analysis. The detailed information about the results of the analysis reported in the next chapter.

### 3.6.2 Observation and Video Tape Analysis

In order to answer first research question, *what are PSTs TPACK levels in three different teaching implementations?* The development in PSTs' performance were evaluated with the help of observation notes, video records and interviews. The TPACK levels rubric developed by Lyublinskaya and Tournaki (2011) was used to determine PSTs' TPACK level. This rubric includes five levels in Niess et al. (2009) to rate PSTs' usage of technology in teaching mathematics. These levels are recognizing, accepting, adapting, exploring and advancing. Recognizing level of TPACK is the first and lowest level to use educational technology in teaching, while advancing level of TPACK is the fifth and highest level. The rubric includes qualitative descriptors for each levels of TPACK in terms of four main components C1, C2, C3, C4. These components were;

- *C1-An overarching conception about the purposes for incorporating technology in teaching subject matter topics,*
- *C2-Knowledge of students' understandings, thinking, and learning in subject matter topics with technology,*
- *C3-Knowledge of curriculum and curricular materials that integrate technology in learning and teaching subject matter topics,*
- *C4-Knowledge of instructional strategies and representations for teaching and learning subject matter topics with technologies.*

The rubric was modified to describe PSTs' technology-based lesson implementation performance by the researcher. In the original rubric the terms "TI-Nspire" was replaced by technology which refers to "GeoGebra Dynamic Geometry Software/ Spreadsheets" since participants of the study were not exposed to TI-Nspire technological device instead participants of the study gained experiences with GeoGebra Dynamic Geometry Software and Spreadsheets in their previous course. The GeoGebra

dynamic geometry program and TI-Nspire are the products constructed to use in the mathematics education. It is possible to design technology-based activities with each of the technological tool to teach a mathematics concept. Therefore, TI-Nspire might be replaced with the technological tool that the pre-service teachers used to teach mathematics.

The rubric is a matrix with levels of TPACK being matched against the four TPACK components. Each cell of TPACK levels rubric represents a TPACK level of one of the four components of TPACK. Each row of the rubric represents a component of TPACK and each column of the rubric represents a level of TPACK. The PSTs' TPACK level is determined based on the indicators for each level separated from each other.

Following Lyublinskaya and Tournaki (2011) rubric items for each level, the researcher utilized the behavior of the PSTs and classified these units into predetermined categories. For instance, dynamic geometry program provides PSTs a spectrum of teaching tools that let them model, demonstrate, hide which mathematical concepts they want to teach. An important feature of dynamic geometry program is modeling real-life problems. Real-life problems are presented in a mathematical context to help students apply math to everyday practices. The researcher checked whether students be given opportunities to search for the solution of the problem from various data sources. With the help of an expert associate professor, criteria that indicate the level of that implementation were decided on for each component. Table 3.7 presents the revised TPACK levels rubric.

Table 3.5 TPACK Levels Rubric

|                                                                                                                         | <i>Recognizing (1)</i>                                                                                                        | <i>Accepting (2)</i>                                                                                                                                                                                            | <i>Adapting (3)</i>                                                                                                                                                                                | <i>Exploring (4)</i>                                                                                                                                                                                                                                                                                                          | <i>Advancing (5)</i>                                                                                                                                                                                                                                                                                                                        |
|-------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>(C1) An overarching conception about the purposes for incorporating technology in teaching subject matter topics</i> | Technology is used for <b>practice</b> only, and all learning of new ideas done through the teacher mostly without technology | Larger part of technology usage was in a way that is new and different from teaching without this technology ( <b>dynamic nature, linked representations</b> ) and used for learning new knowledge by students) | Teacher use technology in a way that is new and different from teaching without this technology ( <b>dynamic nature, linked representations</b> ) and used for learning new knowledge by students) | Larger part of technology is use by <b>students who explore and experiment</b> with it for new knowledge and for practice                                                                                                                                                                                                     | Technology tasks provide students with deeper <b>conceptual understanding</b> of mathematics and its processes                                                                                                                                                                                                                              |
|                                                                                                                         | Technology activities <b>do not include inquiry tasks.</b><br>Technology procedures concentrate on drills and practice only.  | Technology activities <b>do not include inquiry tasks.</b><br>Technology procedures concentrate on teacher demonstration and practice.                                                                          | Technology activities <b>include inquiry tasks.</b><br>Technology procedures concentrate on mathematical tasks with connections and on inquiry activities that use or develop connections.         | Technology activities <b>include inquiry tasks.</b><br>Technology procedures concentrate on mathematical tasks with connections and doing mathematics – and on inquiry activities that use or develop mathematical knowledge of high value: connections (especially between multiple representations) and strategic knowledge | Activities <b>include inquiry tasks</b> of high cognitive demand.<br>Technology procedures concentrate on mathematical tasks with connections and doing mathematics – and on inquiry activities that use or develop mathematical knowledge of high value: connections (especially between multiple representations) and strategic knowledge |

Table 3. 5 Continued

|                                                                                                                                       | <i>Recognizing (1)</i>                                                                                   | <i>Accepting (2)</i>                                                                                                                                                                    | <i>Adapting (3)</i>                                                                                                                                                          | <i>Exploring (4)</i>                                                                                                                                                                                                                             | <i>Advancing (5)</i>                                                                                                                                                                                        |
|---------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>(C2) Knowledge of students' understandings, thinking, and learning in subject matter topics with technology</i>                    | Technology is used primarily for <b>student practice</b>                                                 | Technology is mostly used for teacher demonstrations or teacher-led student-follow work with technology, <b>it is rarely own – both for used for students' independent explorations</b> | Teacher focuses on students' thinking of mathematics while <b>students are using technology on their own</b> – both for learning new knowledge and review of prior knowledge | Teacher focuses on students' <b>mathematics conceptual understanding</b> and serves as a guide of student learning representations, reasoning with technology, not a director                                                                    | Teacher facilitates <b>students' high level thinking with technology</b> (linked and proofs)                                                                                                                |
|                                                                                                                                       | A document does not present any new material, and only provides space for <b>applications and drills</b> | A document mirrors the structure of the <b>textbook presentation</b> of mathematics without active <b>explorations</b>                                                                  | A document <b>provides an environment</b> for <b>students to do mathematics</b> with teacher guidance                                                                        | A document <b>provides an environment for students to deliberately take mathematically meaningful actions on objects.</b> Teacher guidance is necessary in order for students to see the mathematically meaningful consequences of those actions | A document <b>provides an environment for students to deliberately take mathematically meaningful actions on objects and to immediately see the mathematically meaningful consequences of those actions</b> |
| <i>(C3) Knowledge of curriculum and curricular materials that integrate technology in learning and teaching subject matter topics</i> | Teacher <b>does not use technology for learning mathematics</b>                                          | Teacher uses <b>standard approach</b> to the curriculum topics with technology being used as add-on                                                                                     | The technology is used as a <b>replacement for non-technology based tasks</b> in a traditional curriculum approach                                                           | Students are given <b>problem solving tasks</b> with technology and are asked to expand math ideas on the basis of technology explorations                                                                                                       | Teacher uses technology in a fully constructive way, <b>including tasks for development of higher level thinking and deepening understanding of mathematics concepts</b>                                    |

Table 3. 5 Continued

|                                                                                                                                         | <i>Recognizing (1)</i>                                                                                                                              | <i>Accepting (2)</i>                                                                                                                                                                 | <i>Adapting (3)</i>                                                                                                                                                                                             | <i>Exploring (4)</i>                                                                                                                                                                                             | <i>Advancing (5)</i>                                                                                                                                                                                                  |
|-----------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                         | Technology if used is not <b>aligned with one or more curriculum goals</b>                                                                          | Technology is partially aligned with one or more curriculum goals.<br><b>Teacher has difficulty in identifying topics in mathematics curriculum for including Technology as tool</b> | Technology is aligned with one or more curriculum goals.<br>Teacher chooses topics from school mathematics curricula; however, <b>technology use is not always appropriate for the chosen curriculum topics</b> | Technology is aligned with curriculum goals.<br>Teacher chooses important topics of school mathematics curricula and <b>technology use is appropriate for the chosen curriculum topics</b>                       | <b>Technology is strongly aligned with curriculum goals.</b> Teacher chooses essential topics of school mathematics curricula.<br>Technology use is effective for the chosen curriculum topics                        |
| <i>(C4) Knowledge of instructional strategies and representations for teaching and learning subject matter topics with Technologies</i> | Teacher focuses on <b>how to use technology</b> rather than how to explore math ideas, using teacher-directed lectures followed by student practice | The <b>instructions are teacher-led.</b> Teacher structures lesson plan with limited student explorations with technology                                                            | Teacher uses, deductive (teacher- directed) approach with more focus on mathematics discoveries with technology rather than inductive, traditional curriculum                                                   | Teacher uses various instructional strategies (deductive and inductive) and focuses on students thinking about mathematics.<br>Teacher's use of technology is beyond traditional approaches to curricular topics | Teacher focuses on students' hands-on and experimentation of new mathematics ideas with technology, and focuses on conceptual development                                                                             |
|                                                                                                                                         | Technological Activity document provides students only with <b>opportunities for drill and practice</b>                                             | Technological activity document is not built around learning objects and <b>does not promote student reflection</b>                                                                  | Technological activity document is built around learning objects but does <b>not promote student reflection</b> – especially the posing of questions for sense-making                                           | Technological activity document is built around learning objects and <b>must explicitly promote student reflection</b> – especially the posing of questions for sense-making                                     | Technological activity document is built around learning objects and <b>must explicitly promote student reflection</b> – especially the posing of questions for sense-making, including explanation and justification |

The second research question of the study was *to what extent do PSTs develop their TPACK through of the implementation of three technology-based lessons in a field experience?* In order to answer this research question, the change in PSTs' performance was assessed via observation notes, video records and interviews. First of all, each lesson implementation was described via descriptive field notes and video records, then each implementation was evaluated via reflective filed notes based on the TPACK Levels rubric (Lyublinskaya & Tournaki, 2011). Then the associate professor, collaborated in the assignment of categories previously, reviewed the evaluation of PSTs for each implementation and validated the PSTs' performance level based on the TPACK levels rubric (Lyublinskaya & Tournaki, 2011) proposed by the researcher.

#### **3.6.2.1 Reliability and Validity of the TPACK Levels Rubric**

The rubric was tested for reliability and validity (Lyublinskaya & Tournaki, 2011). Content validity was ensured by employing two TPACK experts; both researchers who were involved in the initial development of the TPACK conceptual framework for mathematics educators. They reviewed the rubric and provided written comments in response to three specific free-response questions about the rubric. In order to test for inter-rater reliability, Lyublinskaya and Tournaki (2011) asked two different experts in the field to use the revised rubric. The range of correlations between the scores of two experts on the same components was from  $r = 0.613$  to  $r = 0.679$   $p < .01$ . Correlations that examined whether there was a relationship among the four components of the rubric for each expert were also found statistically significant, i.e., the range of correlations for Expert 1 was from  $r = .85$  to  $r = .94$   $p < .01$  and for Expert 2 was from  $r = .93$  to  $r = .97$   $p < .01$ .

Lyublinskaya and Tournaki (2013) completed a factor analysis using varimax rotation with Kaiser normalization to confirm construct validity of the rubric when applied to pre-service special education teachers. The procedure was performed on 182



lesson plans collected during two semesters. For this sample size Stevens (2002) suggests that loadings greater than 0.512 can be considered significant, thus, all values less than 0.590 were suppressed. The procedure confirmed that four factors of TPACK corresponded to the four components of PCK for each set of lesson plans (Lyublinskaya & Tournaki, 2013). This was the only rubric presently available to mathematics educators working in the field of TPACK at the time of this study. In the other research studies this rubric was also used to assess participants' TPACK performance (Lyublinskaya & Tournaki, 2011; McBroom, 2012; Mudzimiri, 2012).

In the present study, TPACK levels rubric was used to assess PSTs' performance in technology-based lesson implementations. In order to complete inter-rater reliability of the lesson implementations researcher asked a rater, who is experts in the content, pedagogy and technology of the lessons implementations, to watch the video-records and lesson descriptions and rate the rubric. Rater was a middle school mathematics teacher for 10 years and has a master degree in mathematics education. Before rating process, researcher explained how to use the rubric to rate the lesson implementation and then they discussed the meaning of each criterion. Some of the example artifacts were rated and discussed to agree on criteria of the rubric. After that rater watched video-records of the lessons (read the lesson descriptions for the case Ali) and do scoring independently. She rated each lesson implementations based on the four component of TPACK. The pearson product-moment correlation coefficient is the commonly used statistics in literature to calculate the degree of consistency between independent raters. Values approaching +1 or -1 means that the raters are following a consistent pattern, whereas values close to zero means that it is almost impossible to predict the rating of one judge given the rating of the other judge. An acceptable level of reliability using a pearson correlation is .70 (Multon, 2010). The Pearson correlation calculated for the present study was  $r(34) = .73$ ,  $p < .01$ . There is a 73 % consistency between researcher and rater's scores. TPACK levels rubric developed by Lyublinskaya and Tournaki (2011) is presented in Appendix D.

### **3.6.3 Document Analysis**

The documents used in document analysis process were PSTs' lesson plans, reflection paper prepared for ELE 435 and ELE 420 courses and middle school students' reflection papers related to PSTs' implemented lesson. Lesson plan included lesson objectives, prerequisite students knowledge, sequencing of the lesson (starting, middle, closing, extension (optional), assessment), activity sheet, anticipated students' answer (optional), technical information about how to construct GeoGebra activity. Lesson plans were used in describing lesson implementations and triangulate the pre-interview data for each lesson implementation. Lesson plan was used as a checklist to determine whether PSTs implement what they planned. Reflection papers used as an additional data source to seek for PSTs' personal ideas about their experiences in teaching practice. In lesson descriptions this information was shared with the reader. Summary of the middle school students' reflection papers were also shared in the lesson descriptions to triangulated the data.

### **3.7 Quality and Ethic Issues**

Ethics rules of human resource in Middle East Technical University had been met by obtaining necessary permission from the Applied Ethics Research Center in Middle East Technical University. At the beginning of the study, the researchers meet with the participants to explain the aim of the study and asked if they wish to participate in. PST was informed about what they are supposed to be if they were voluntary to involve in the study. The participants of the study were guaranteed about anonymity to keep their data confidential (Creswell, 2007). There was no deception or procedures that jeopardize participants' physical or mental health. There was no possible risk or interview questions which causes participants feeling bad or gets harm. Six PSTs agreed to participate in the study. Participants signed consent forms indicating their willingness to participate in the study and they have an option to exclude themselves from the study whenever they

want. Pseudonym names were used for the participants and all information obtained from participants kept strictly confidential and utilized only for research purposes and in five years will have been destroyed. While PSTs implement technology-based lesson, researcher videotaped their lesson and took observation notes. Then she interviewed with each participants eight times. The debriefing for participant was prepared to share study results with them.

### **3.8 Limitations of the Study**

There are limitations that can affect the generalizability of the reported results include;

- The population of students accepted into the teaching program at the METU is inherently biased. These students pose strong content knowledge.
- Since participants had content, methods and technology courses in their training program, it is assumed that participants of the study have pre-knowledge to improve their TPACK.
- The PSTs had to teach the assigned curriculum objectives.
- Limited amount of teaching practices (5-6 class-hours) were implemented at collaborating schools.
- The educational technology was limited with GeoGebra and Spreadsheet software.
- The computer lab used in the study was traditional including fixed seating and weren't well suited to group work or discussion.
- A case study methodology was used with a small number of participants, which caused limitation of the generalizability issue.
- Researcher bias was possible since the researcher worked as a facilitator in the study.

## **CHAPTER IV**

### **FINDINGS**

This chapter presents the findings of the present study. The purpose of the study was to investigate the change in PSTs' TPACK levels based on the TPACK levels rubric developed by Lyublinskaya and Tournaki (2011) within the context of their teaching practices, the extent of the development in PSTs' TPACK through of the implementation of three technology-based lessons and their interpretations about this experience. This part divided into two parts, to report findings of the research questions. In the first part, findings related to first research question; what are PSTs TPACK levels in different teaching implementations? and second research question; to what extent do PSTs develop their TPACK through of the implementation of three technology-based lessons in a field experience? were documented. In the second part, findings related to third research question; how do PSTs interpret their experiences with educational technology throughout the implementation of three technology-based lessons lessons in a field experience? were reported.

#### **4.1 Findings of Research Question I and II**

In order to report the findings of the first and second research questions, first of all, each lesson implementation explained in detail. Then general overview about change in PSTs' TPACK levels based on the TPACK levels rubric developed by Lyublinskaya and Tournaki (2011) was determined with evidences.

PSTs' lesson implementations were described based on four main data sources; lesson plan, pre and post interview, videotape and observation notes. Time stamps was used to highlight the time of the action. Lesson plan and pre interviews data were used to

describe the classroom or computer-lab environment and aim of the technology-based activity. Video records and observation data were used to give information about the teacher and students role, student-teacher dialogs, teaching methods, the way to using educational technology and overall evaluation of the lesson based on the TPACK levels rubric developed by Lyublinskaya and Tournaki (2011). Middle school students' answers to reflective questions related to implemented lesson were also used as an additional data source. Post interview data were used to analyze PSTs' self-evaluation of the implemented lesson and their plans for the next implementation. In addition, PSTs' reflection papers were used to report their general idea about this implementation process.

In the study, there were three criteria in selecting lesson objectives for the participants. First of all, their lesson objective should fit into the mentor mathematics teachers' time schedule. Secondly, lesson objective should be consistent with National Curriculum. Finally lesson objective should be available to teach with educational technology. Chosen objectives in this study were aligned with these three criteria.

#### **4.1.1 Case of Meltem**

This section presents the findings regarding the case of Meltem. Findings related to the changes and adaptations observed in Meltem in terms of TPACK level throughout the implementation of three technology-based lessons during the field experience was explained in the subsequent sections.

##### **4.1.1.1 Findings of Meltem's First Implementation**

Meltem implemented her first lesson via GeoGebra program with 29 eighth grade students in the classroom, not in the computer lab. Class included projector and white board, but not computer. Meltem used researcher laptop to project the GeoGebra activities on the board. The first technology-based activity that she prepared for the

lesson was her final project for ELE 430 course she took previous semester. Second activity was a problem that was adopted from Japanese lesson study and she had already known from previous courses. This problem was modeled via GeoGebra program by Meltem to ask students in the lesson. She was familiar with the students and classroom environment, since she had already been in this class for observation in the context of field experience course. The subject of the lesson was area of a triangle. Lesson objective was; the area of triangles is equal when they have same base and same height. Meltem and mentor teacher decided lesson objectives together and mentor teacher confirmed that subject is available to teach for this lesson. The teaching method that she planned to use was problem solving. The aim of the technology-based activity was to have students discover the area of triangles is equal when they have same base and same height. Students were asked to construct a triangle having the same base and same area as a given triangle. Her goal to use technology in this lesson was to model a dynamic problem and use it to ask questions to the students about the solution of the problem. Meltem planned to be a guide in the lesson to have students reaches the lesson objectives. She knows from her mentor teacher that students have necessary prerequisite knowledge to participate in class discussion. Meltem felt ready to teach and had no concern about lesson implementation before the lesson. The duration of the lesson was 80 minutes.

At the beginning of the lesson she introduces herself to the students and told about what mathematics topic she would teach. Then she started lesson by introducing GeoGebra program since this was the first time that students met this program. Then she projected the first question, as stated Figure 4.1, on the white board via projector and asked students to solve the problem with pencil and paper. She distributed the activity sheets named “make triangle” and gave them two minutes to think about the first problem.

How can you create a single triangle which has the same area with the polygon given below? Provide your reasoning.

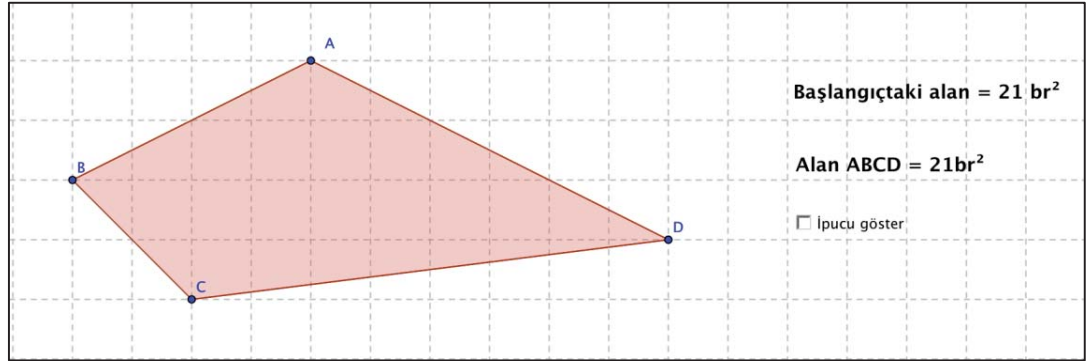


Figure 4.1 Meltem's first problem

Note. English translations of Turkish words “Başlangıçtaki alan” is original area, “Alan ABCD” is area ABCD, “İpucu göster” is show the hints.

Then she asked students about their ideas related to the problem and let them discuss. The discussion lasted approximately 10 minutes. After that, she opened the GeoGebra file and projected it on the white board. 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. Meltem asked students if there is any volunteer to fix the area of triangle and original quadrilateral, by moving one of the dynamic vertex points as stated in Figure 4.2.

When student move the one of the dynamic vertex point of the quadrilateral he saw the change in the areas of the shapes and tried to fix them up. He tested when it could be constructed a triangle with the same area as the original quadrilateral via dynamic text box which includes the measurement of the areas. However the problem had not been solved yet. Meltem directed students to think about the problem via asking questions.

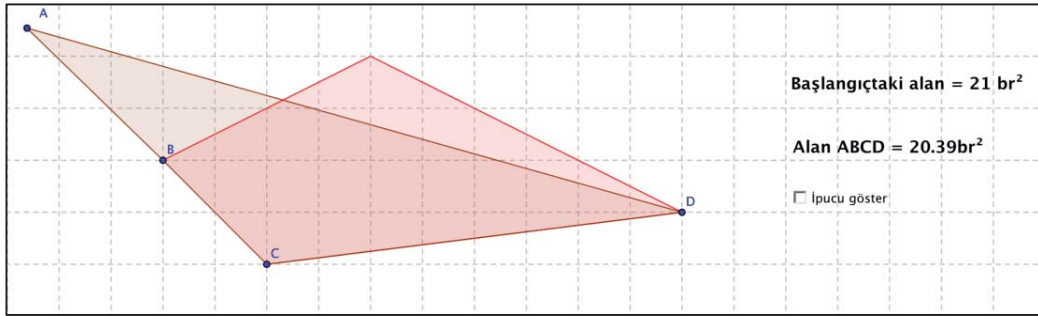


Figure 4.2 Moving point A

Meltem asked “we cannot expect from GeoGebra to solve the problem. We have to explain its reason why the areas are equal. So the question is “we have a quadrilateral and it has four vertex, we want to make it triangle, so what can we do? [v.11:00-11.07].

Meltem asked students how could they omit one of the vertex and wanted them to explain their conjectures. One of the students proposed that; we need to omit one of the vertices of the polygon to make it triangle. Therefore, we can take one of the vertices and drag it on to the other side of the polygon [v.11:09-11.12]. Meltem repeated after student answer, you propose to carry one of the vertex points on the extension of the other side, very nice [v.11:13-11.15].

Then to display students carrying one of the vertex points on to the extension of the other side, she opened GeoGebra file. Meltem prepared hints to the students to support them to solve the problem. She clicked on the checkbox in the GeoGebra file named “Show the hints” and moved the slider named “step1” as stated in Figure 4.3 and “first hint related to this” she said. [v.11.17-11.25].



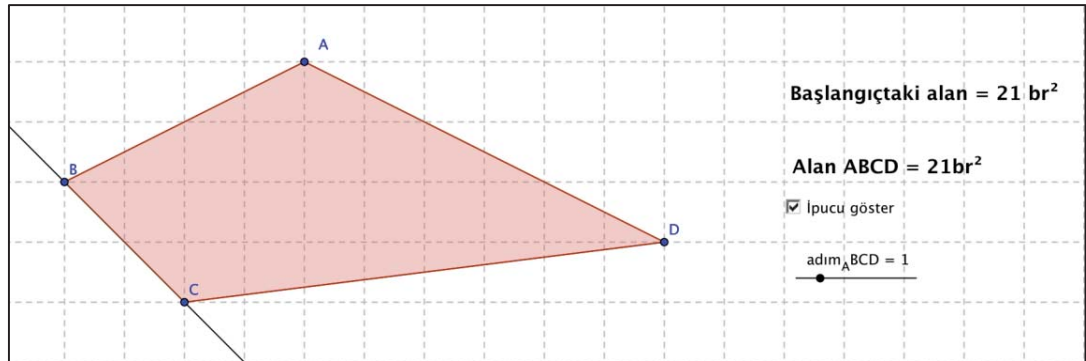


Figure 4.3 First step hint of Meltem's first problem in first lesson.

*Meltem: As you see GeoGebra has drew a line on the BC side of the polygon. Why do you think we need this line? [v.11.37-11.40].*

*Student: It fixed two vertexs stable, so we need to carry either A or D on to the line passes through BC side. [v.11.42-12.50].*

*Meltem: Yes we need to move one of them. Same logic with your friend's as he stated previously [v.11.50-12.55].*

She asked for volunteer students to give one more try with GeoGebra to solve the problem. One of the students come to the laptop and tried to fix them up. However there was still no exact solution for this problem.

*Meltem: When we joint point B and point D with a line is there any change? [v.14.50-14.55].*

*Students: Nothing happened.*

*Meltem: Ok then think about beyond of the BCD triangle? Is there anything familiar to you? [v.14.57-15.02].*

Meltem asked questions to have student think about the two triangles and share their opinions.

*To keep the areas equal which triangles' areas should be equal? [v.15.02-15.07].*

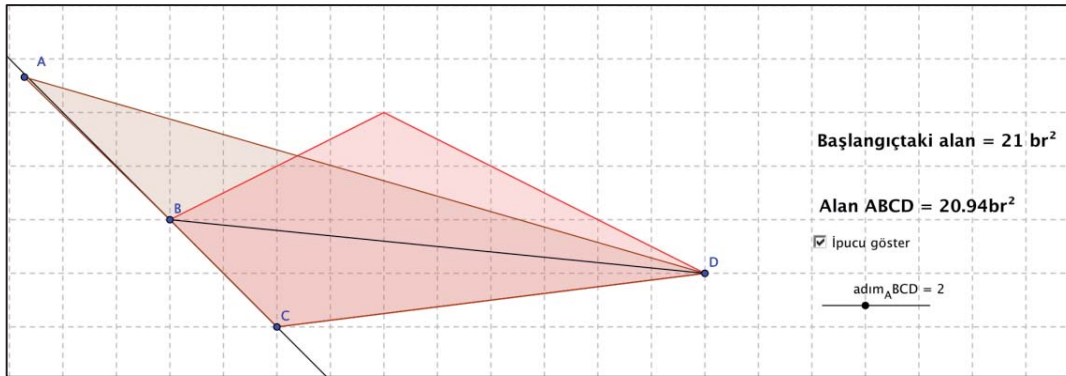


Figure 4.4 Second step hint of Meltem's first problem in first lesson.

*Student: The area of triangle these two triangles should be equal. [v.15.24-15.27].*

*Meltem: How can we be sure that, these triangles' areas are equal? [v.15.27-15.29].*

After thirteen minutes wait time she took student attention to the triangles and asked. (See Figure 4.4)

*Meltem: Look at triangles and try to see their common characteristics, what is that? [v.16.12-16.15].*

*Student: They have the same base line. [v.16.18-16.22].*

*Meltem: Yes they have the same base line, haven't they? [v.16.22-16.24].*

*Meltem: We want to make their areas equal, we have equal base line so what we need now? How can we calculate the triangle area? [v.16.24-16.34].*

*Student: Multiple baseline and height of the triangle (which belongs to base line) and divide into two. [v.16.35-16.37].*

*Meltem: Himm you mean that Point A and the other triangles' top point should be equal distance from base line. ... How can we measure it? [v.16.37-17.07].*

*Student: With ruler!!! (laughing in the class). [v.17.07-17.09].*

*Meltem did not laugh and asked if they want more hints. Students asked her to repeat the question. She repeated the question and gave approximately one minute wait time.*

*Student: If their areas are equal and they have the same base line, their height should be equal already. [v.17.55-18.01].*

*Meltem: Yes you are right, however it doesn't mean that we solved the problem. You don't have GeoGebra every time to see. We need to prove it. [v.18.15-18.26].*

In order to show students the mathematically meaningful consequences of those actions, Meltem worked as guide. Meltem incorporated technology in teaching subject matter topics by giving hints step by step to students when they are needed. She let students to think more and then asked students if they want to see third hints. Students loudly said that they want to see the hint then she showed the third hint as stated in Figure 4.5.

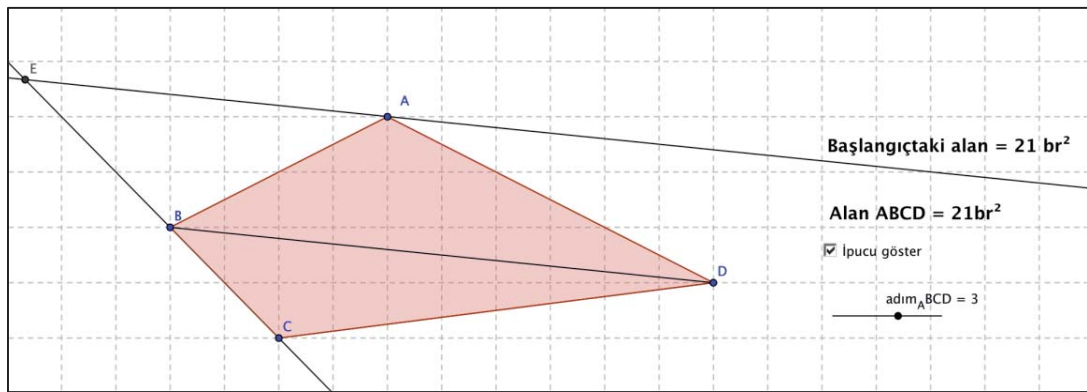


Figure 4.5 Third step hint of Meltem's first problem in first lesson.

The discussion continued.

*Student: Teacher you gave the answer instead of hint I think. [v.20.30-20.38].*

*Meltem: No I did not, what is your answer? Why I draw that line do you think? [v.20.39-20.40].*

*Student : I think we need to carry point A to point E. [v.20.40-20.41].*

*Student : I think these lines are parallel because the distance between parallel lines are equal. [v.20.41-20.44].*

*Meltem: Yes you are right let me check what will happen if I carry point A to E.*

Then she checked the students' suggestions via GeoGebra and displayed the measurements of areas were equal via dynamic text boxes in GeoGebra file. The correct reasoning was identified in the class discussion which was *we have drawn a parallel line to BD passing through point A. Then any triangle with base BD and the other vertex on this new line has the same area with ABC triangle.* Meltem had students write this

reasoning in the corresponding part in their activity sheets. At the same time she invited one of the students to solve and explain the answer. (See Figure 4.6)

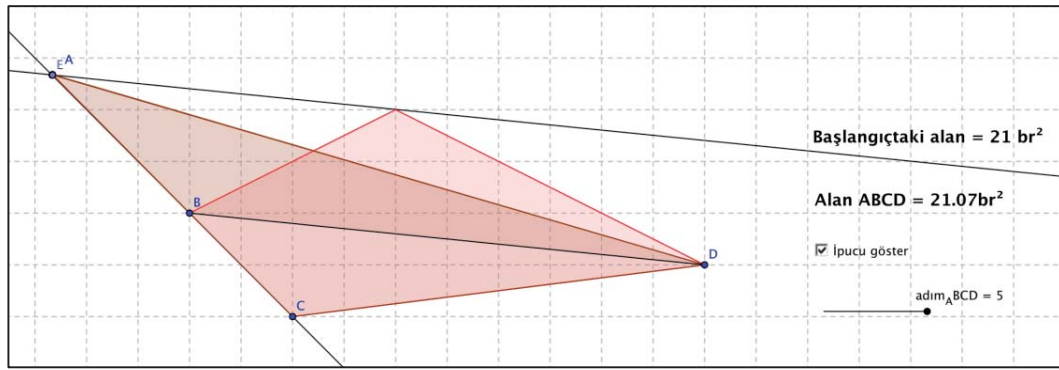


Figure 4.6 Solution of the first problem

The bell had been rung and students went out for break.

In this activity, Meltem generated an example for students to observe and make conjecture about mathematical concepts. For example, Meltem gave student an opportunity to move the vertex points of the quadrilaterals and try to construct a triangle with the same area as the original quadrilateral. While doing this, students could compare two areas by the text boxes in which areas calculated within the dynamic text and observe the change in the areas. Via checking the texts on the right hand side of the activity file, student realized that the area of triangles, which have the equal base line and height, are equal. During this process the other students observed the activity without active exploration.

Up to now, GeoGebra program help Meltem display hints related to solution of the problem. While showing hints, she asked questions to have students think about the solution of the problem. Student could confirm their reasoning via these examinations with the help of GeoGebra program. At the end of the lesson, student solved the problem. Meltem finished the first 40-minute lesson. Ten minutes later second 40-minute-lesson was started.

After asking, whether there is anything that they did not understand related to previous problem, Meltem dragged the Geogebra file to demonstrate second problem to the students.

*Meltem: Is everybody with me? The new problem is very similar to previous one. It might be solved with same logic. [v.04.47-05.11]* She said and showed the problem in Figure 4.7.

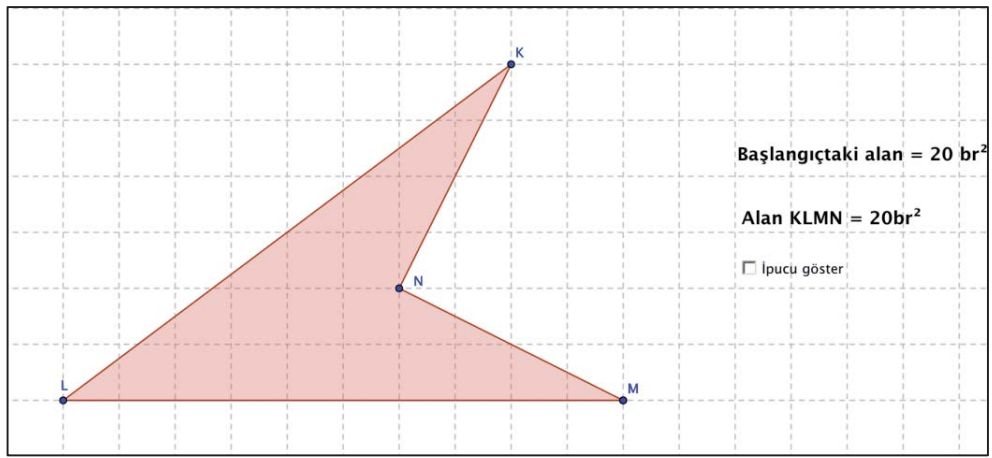


Figure 4.7 Meltem's second problem

Meltem remind that problem was *How can you create a single triangle which has the same area with the polygon given below? Provide your reasoning [v.06.10-06.19].*

She asked students to solve the problem with pencil and paper. She gave them two minutes to think about the second problem and write their reasoning on activity sheet.

*Let's keep going, what we need to do first? How can we make a triangle from this polygon? We need to change the location of which point or points this time? [v.07.40-07.49].*

*Choral response from students: Point K, Point N, Point M, No matter K or M.[v.07.49-08.21].*

*Meltem: Who wants to give a try? [v.09.18-09.22].*

A student raised his hand and, after Meltem's confirmation, came near to the laptop. He dragged point N and tried to make a triangle with the same area. However he

noticed that the more he dragged point N to the right side, the more area was bigger than original one. So he changed his mind and started to drag point K to the left side. [v.09.30-09.51].

*Meltem: Dragging which point helped you to make the geometrical shape triangle and closed the measure of area that you want? [v.09.58-10.07].*

*Student: K worked. When I dragged the point K to the right side, the area was closed the original one. [v.34.08-34.15].* Then student went back to his desk.

*Meltem: Can you explain the reason why K worked mathematically? [v.10.15-10.20].* She asked to the class.

*Student: Shall I answer? We can do same thing what we did previously. Firstly we need to joint point N and L then we draw a parallel line from K to NL line [v.11.43-11.19].*

*Meltem: These were the first and second hints for you. Let's come to the laptop and verify your explanation. [v.11.20-11.40].*

Student came to laptop and jointed points N and L then draw a parallel line to this line from K as stated in Figure 4.8.

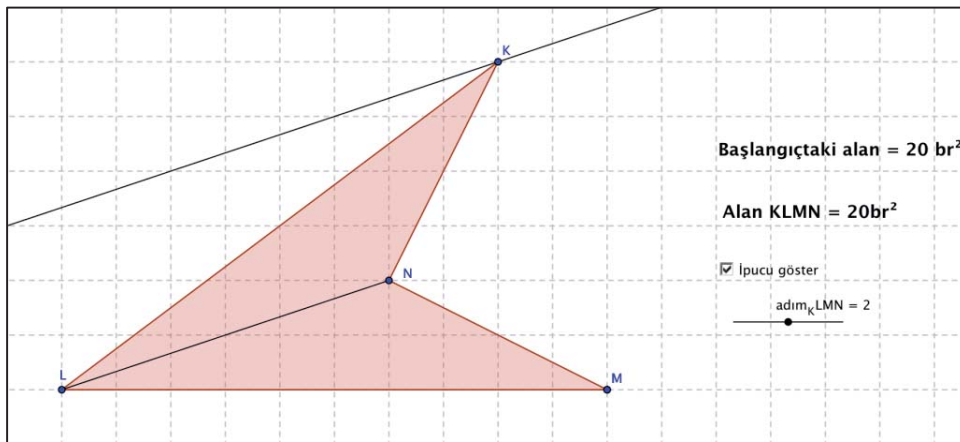


Figure 4.8 Student's first step of the solution

*Meltem: What is next step? How can we find the point that we are looking for to fix the areas equal? [v.11.50-11.54].*

Meltem wait almost thirty seconds there were no answer from students. Meltem didn't asked probing questions to challenge students to explain their opinion about the geometric task. She continued with questioning;

*Meltem: What we said about parallel lines?*

*Choral response from students: The distance between two parallel lines is constant. [v.12.01-12.12].*

*Meltem: Then does it make sense with you? [v.12.13-12.15].*

*Student: The point that we are looking for should be on the line, passing the point K, because we want to create a triangle with the same base line and height with KLN triangle [v.12.43-13.12].*

*Meltem: Yes you are right. Well, how can we find the exact location then? [v. 14.15-14.28].*

*Student: The point should be the same direction with point N because we want to create a triangle. [v. 15.16-15.40].*

Meltem invited another student near to the laptop to demonstrate what he meant. Student drew line through point M and Point N then, he found intersects points with the other line and called it G. Student said G is the point they were looking for. Students' presence of point G stated in Figure 4.9.

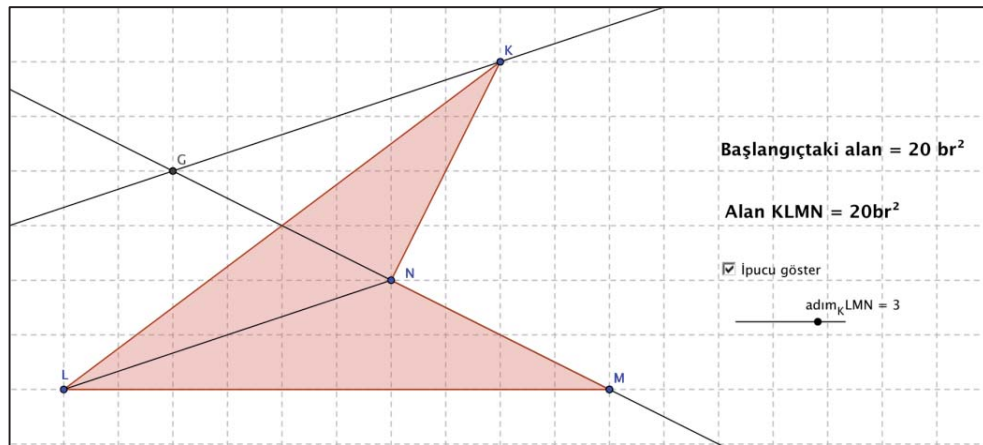


Figure 4.9 Student's presence of point G

*Meltem: Do you agree with your friend? [v. 16.15-16.20].*

*Choral response from students: Yes [v. 16.22-16.24].*

*Meltem: Lets check it out via hints. [v. 16.25-16.45].*



Then she moved the hints slider at the end showed the correct answer she prepared previously via GeoGebra as stated in Figure 4.10 and Figure 4.11.

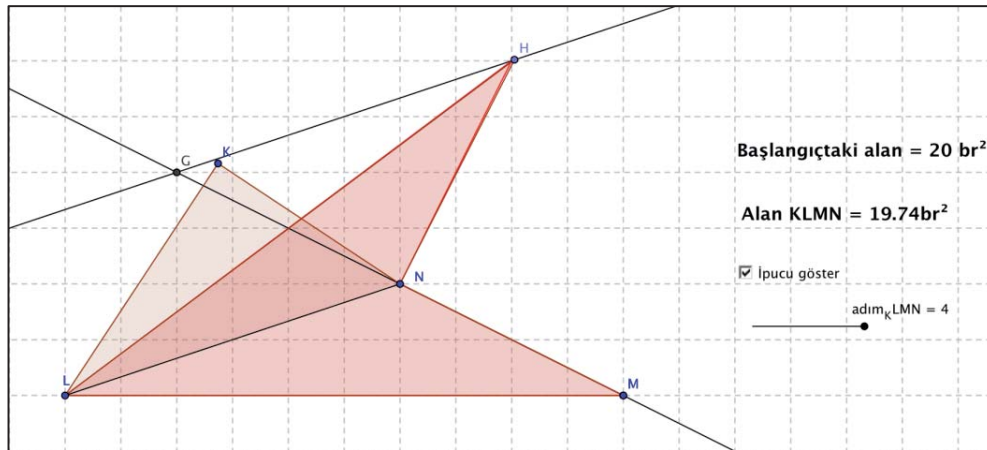


Figure 4.10 Checking the answer by dragging point K to point G

She had a technical problem at this time and couldn't fix the points. The exact window she wanted to show stated in Figure 4.11.

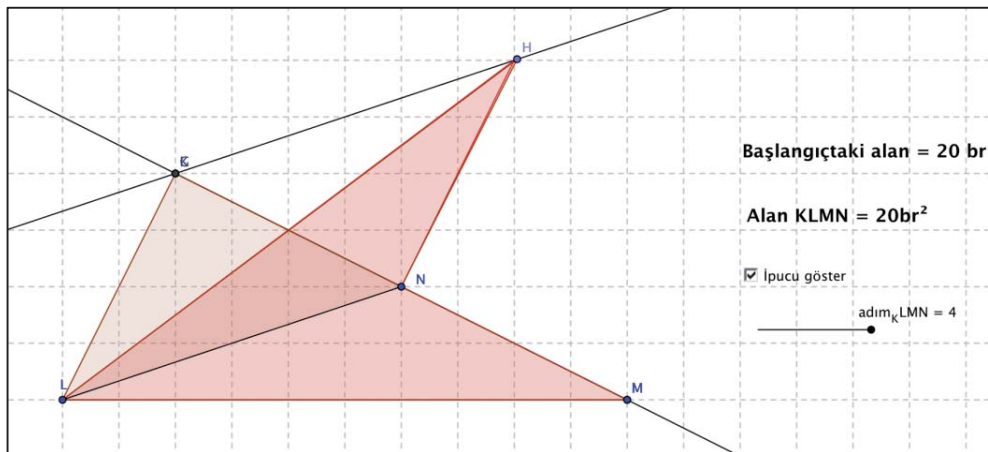


Figure 4.11 Solution of the second problem



In this example, the GeoGebra activity procedures concentrated primarily on analyzing and solving the problem step by step by giving hints to the students in order to have them recognize the area of triangles, which have the equal base line and height were equal. In this activity, her goal was to have students make judgments based on their exploration via GeoGebra activity through checking and critiquing. However since the lesson was not implemented in the computer lab, students didn't have a chance to make this exploration individually. In addition the questions that she asked didn't challenge them to discover geometric rule by themselves. With the help of dynamic nature of the GeoGebra, Meltem provide students an opportunity to observe the relationship between geometrical concepts and obtain the logic behind the rule. After solving these two problems, to assess student understanding, Meltem distributed activity sheet for last problem as stated in Figure 4.12.

This real life problem was adopted from Japanese lesson study, which she studied in one of her courses in the university. The problem was;

*The following figure belongs to two distinct boundary lines separating the two land one another. These two people decide to redraw the border into a single segment. However, there is one condition that it should be fair sharing. Can you help them? And how can you convince them, the amount of land they have did not change?*

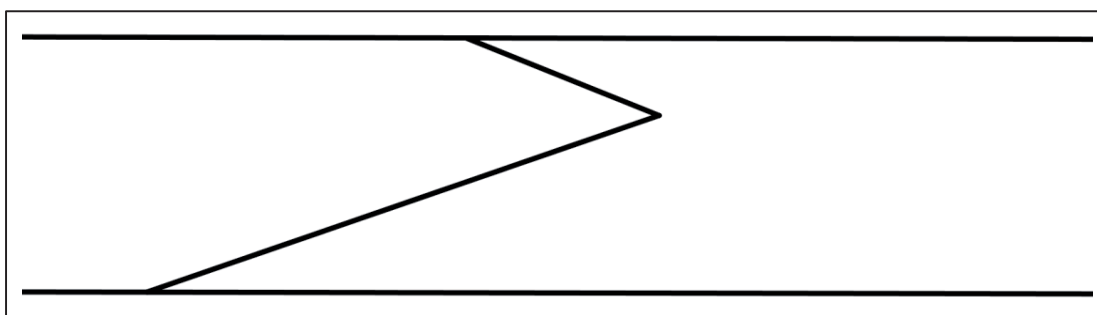


Figure 4.12 Assessment problem

Meltem gave students two minutes to think about the real life problem. Then she asked.

*Meltem: Is there anyone who wants to explain the problem, what it wants from us? [v. 19.45-19.52].*

*Student: We need to draw a boundary line. [v. 19.54-19.56].*

*Student: It should be a single segment [v. 20.02-20.05].*

Meltem repeated his answer while drawing the problem figure on the board.

*Meltem: Is there any idea? [v. 20.15-20.18].*

*Student: Well, do we need to draw a triangle from here? [v. 20.21-20.23].*

He asked to complete the figure and make a triangle.

*Meltem: That might be work, try it [v. 20.23-20.25]. Meltem toured in the class.*

*Student: We can draw it with GeoGebra and measure the area. [v. 20.35-20.38].*

*Meltem: How can we measure it? It is not a closed shape, isn't it? [v. 20.40-20.43].*

*Student: We can close it to make a triangle. [v. 21.43-21.47].*

Meltem walked to the board with a magnetic ruler in her hand and she pasted it the place that student suggested.

*Meltem: Is it fair sharing now? [v. 22.30-22.35].*

Students said “no” chorally.

The student who suggest close the two lines with corner to make a triangle, wanted to come to the board and explain what he meant. Students came to the board and draw a line segment and constructed EAC triangle. Meltem confirmed student. Then Meltem asked class to solve this problem practicing on previous solutions. Another students raise her hand then came to the board and shared her idea.

*Student: We can draw a parallel line from E to AC line [v. 25.37-25.42].*

The figure on the board at that time was displayed in Figure 4.13.

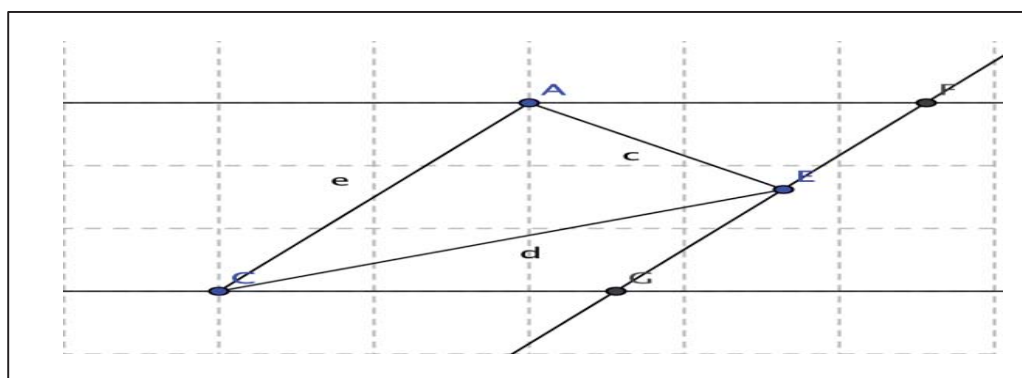


Figure 4.13 Student's suggestions

Meltem drew the parallel line with chalk on the board.

*Meltem: What is next? [v. 22.30-22.35].*

She gave students five minutes to think. Then students shared their ideas with class. Most close students solution to the correct answer was come from another student.

*Student: We can move the point E to point F or point G to make the border a straight line as we did in previous lesson. [v. 28.57-29.28].*

Students suggestion stated in Figure 4.14.

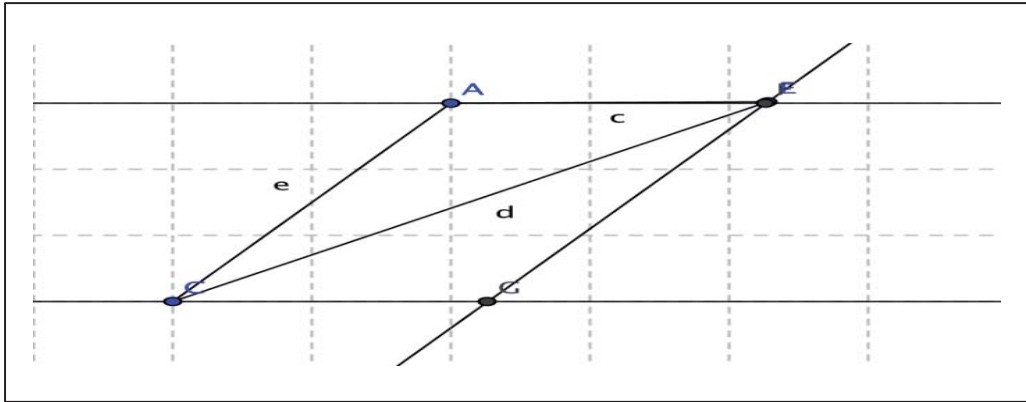


Figure 4.14 Solution of the real life problem

*Meltem: Perfect. What did your friend say? Did you understand? [v. 29.30-29.41].*

She said while drawing straight line from point C to point F.

*Meltem: Is it correct answer?*

Some of the students said “yes” while the others said “no” chorally.[v. 29.43-29.48].

*Meltem: Please speak one by one to explain your reasoning.[v. 29.50-29.55].*

*Student: That is ok. We solved the problem I think.*

*Meltem: Is it correct answer?*

Some of the students said “yes” chorally.[v. 29.43-29.48].

In summary, GeoGebra program provided students a dynamic environment to express their ideas about the solution of the problem. Students were interested in the lesson and actively engaged the discussion to pose their ideas. Then Meltem explained the solution once again for these students and finished the lesson.

#### **4.1.1.1.1 Student Reflection**

At the end of the lesson, Meltem asked students to write a reflection paper, in order to evaluate the lesson from students' point of view. The questions for this paper were;

- 1) What have you learned in today's lesson? Explain briefly?
- 2) What do you think about the use of technological tool while learning this geometric issue? Explain your reasons.
- 3) In which part of the lesson you enjoyed?
- 4) In which part of the lesson you bored?
- 5) How do you evaluate your performance in class discussion? What was the most difficult part for you? If you give yourself a score out of 10 what would be this score?
- 6) Is there anything that you want to add related to this lesson?

During the last five minutes of the class time, students were asked to write their reflections to the lesson to provide feedback about the lesson implementation to Meltem. For doing this, Meltem projected the set of reflective questions stated above on to the board. Twenty-three out of 29 students wrote their comments about the lesson via answering open response reflective questions at the end. Six of the students didn't want to share their opinion about the lesson. 20 out of 23 student comments about the lesson were favorable. Students were pleased to have been taught this topic via GeoGebra program. Ten of the students reported that GeoGebra is an opportunity to have better insight about the geometrical rule. One of the student comment was, "GeoGebra helped us to see concrete examples about geometrical rule. I could change the (dynamic) vertex points of quadrilateral to make it triangle via GeoGebra and control when the areas are close each other or vice versa." Five of the students stated that GeoGebra very effective

to model real life problem. Seven of the students reported that GeoGebra program took their attention and focused on the class discussion. Especially students gave positive feedbacks to the hints in GeoGebra activity, since hints helped them to solve the problem.

#### **4.1.1.1.2 Meltem's First Lesson Performance**

PSTs' performance was evaluated based on the TPACK levels rubric developed by Lyublinskaya and Tournaki (2011). For detailed information see 3.6.2.

In the first lesson, Meltem's performance for the C1 was consistent with the adapting level. C1 mainly related to the purposes of integrating technology in teaching mathematics. In adapting level, *teacher use technology in a way that is new and different from teaching without this technology (dynamic nature, linked representations) and used for learning new knowledge by students*). The goal of the usage of technology in this lesson was to model a problem and give hints to students in order to assist them in solution process. The problem was "constructing a triangle with the same area as the given (convex/concave) quadrilateral". The usage of educational technology was crucial in this lesson. As explained in detail in the description of the lesson implementation, the dynamic vertex points of the quadrilateral provided students to fix the areas. Dynamic text boxes were helpful to demonstrate the measures of the areas. Students could see in when the areas were equal by moving the vertex points. Meltem used technology to give students hints when they need. The usage of technology was new and different from teaching without this technology. 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. Without this technology it would be more difficult to have students observe the geometric situations in a dynamic way and give hints about solution of the problem.

Meltem's performance for the C2 was consistent with the accepting level. C2 mainly related to the PSTs' knowledge of students' understandings, thinking, and learning in technology-based mathematics lesson. In accepting level, *technology is mostly used for teacher demonstrations or teacher-led student-follow work with technology; it is rarely used for students' independent explorations*. Via technology, she demonstrated the problem task and assisted students step-by-step by giving hints in solution process. Students followed the lesson via hints and tried to complete the missing part in the activity sheet. Meanwhile, she had anticipated the errors that students made and checked their ideas via GeoGebra program. The questions that she asked were so high level for students that most of the students couldn't answer. Technology was rarely used by students since design of the lesson wasn't appropriate for students' independent explorations. Instead of making students actually doing mathematics, Meltem used GeoGebra for demonstrating this lesson considered in accepting level.

Meltem's performance for the C3 was consistent with the exploring level. C3 mainly related to the PSTs' knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics. In exploring level, *technology is aligned with curriculum goals. Teacher chooses important topics of school mathematics curricula and technology use is appropriate for the chosen curriculum topics*. In this lesson, there was no specific lesson objective from the National Curricula. GeoGebra task was planned to explicitly promote student previous knowledge by posing of questions for sense making. The prerequisite knowledge to solve the problem was *"the area of triangles is equal when they have same base and same height"*. It was a basic and important geometry content in the curriculum. There was a sequence between technology-based activities. The starter problem on creating a single triangle, which has the same area with the polygon, created a base line for the solution of the second problem. To solve the second problem, students generalized the rule to concave polygon since they were familiar with the logic behind the rule when the polygon was convex. Finally these two problems constructed the necessary pre-knowledge for the solution of

third problem. This lesson was well structured and GeoGebra task was built around learning objective.

Meltem's performance for the C4 was consistent with the adapting level. C4 mainly related to the knowledge of instructional strategies and representations for teaching and learning mathematics via technology. In adapting level *teacher uses, teacher- directed approach with focus on mathematics discoveries with technology*. In this lesson, Meltem used teacher direct approach and she assisted her teaching via technology. Technology provided environment to demonstrate dynamic model of the problem and give students hints about the solution of the problem. The hints were helpful for students since they included necessary information to solve the problem. The hints were divided into steps and were given to the students at right time when they need to go over to the next level in solution process of the problem. Meltem implement an interactive lesson by getting students out to board and through class discussion. However, limited number of students had a chance to use technology individually and made exploration.

#### **4.1.1.1.3 Post Interview I**

After implementing the first lesson, Meltem was interviewed to reflect on her lesson implementation. During this interview she asked to share her opinions about the lesson implementation. Her performance to use educational technology in teaching were criticized by herself in terms of purpose of the activity (cognitively challenging), the role of the teacher (a guide and help students focus on reasoning), and role of the questions (to led students explore mathematical concepts, discover relationship between mathematical concepts).

In her opinion, the technology usage was very essential in this lesson. Without this technology it was still possible to give hints to the students verbally and visually. However, the advantage of technology was only providing students a chance to observe



the motion dynamically and make an interpretation about the area of triangles. It saved time since they drew the line easily with the help of GeoGebra menu. During the interview, she stated that educational technology needed to be integrated into mathematics to have students explore geometrical concepts and challenge them via questions and support their reasoning via hints. She reported on the main issues that have been discussed in the interview were;

I think, my GeoGebra activity provide students an environment to explore geometrical concepts and make an experiment to solve the problem. The hints in GeoGebra file challenged them to answer the questions that I asked. I think the activities that I designed with GeoGebra engage students into the lesson and supported their conceptual understanding. However, I didn't give enough wait time to the students to think about the mathematical concepts. Not all of the students participated in the class discussion. It would be better if I give each students a chance to interact with GeoGebra activity. Next time I am planning to use similar teaching methods via GeoGebra program, but I will give longer wait time to the students.

#### **4.1.1.2 Findings of Meltem's Second Implementation**

Meltem implemented her second lesson via GeoGebra program in the computer lab with 23 eighth grade students, who were the same students in previous lesson. Computer lab includes 15 computers, a teacher laptop and projector and white board. Every one or two students could have one computer during the lesson. Meltem used teacher laptop to project her GeoGebra file onto the white board. Before the lesson started, three GeoGebra files constructed by Meltem were loaded on students' computers in the lab. The technology-based activities that she prepared for the lesson were adaptation of one of the write up problems related to circumcenter of triangle in ELE 430 course. Meltem's solution for this write-up problem is presented in Appendix E. She was familiar with the students and classroom environment, since she had already implement her first lesson with them and she has also been in this class for observation in the context of field experience course. The subjects of the lesson were finding the

circumcenter of a triangle. Lesson objectives were; the students will be able to construct circumcenter of a triangle and the student will be able to construct the relationship; circumcenter of an acute triangle is inside the triangle, circumcenter of a right triangle is on its hypotenuse; circumcenter of an obtuse triangle is outside the triangle. Meltem and mentor teacher decided lesson objectives together and mentor teacher confirmed that subject is available to teach for this lesson. The teaching method that she planned to use was problem solving. The aim of the technology-based was modeling a real life problem. Her goal to use technology in this lesson was to have students make an experiment and discover the how to find a circumcenter of a triangle. Meltem planned to be a guide in the lesson to have students reach the lesson objectives. Meltem felt ready to teach and had no concern about lesson implementation before the lesson. The duration of the lesson was 80 minutes.

To implement the lesson, Meltem constructed two GeoGebra files. In the first file, she generated a trial file for students to observe and make conjecture about the exact place for circumcenter of an acute triangle. In the same file she construct another part to have students find circumcenter of an acute triangle. In this part she gave hints for the students and hide them 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. Detailed information about the hints was given in lesson description by the researcher. In the second file she simulated circumcenter of a triangle dynamically therefore students observed the change when by dragging one of the vertex point of the triangle. Students first made acute triangle and observed that circumcenter of a acute triangle is inside the triangle, then they made a right triangle and observed that circumcenter of a right triangle is on its hypotenuse and finally they made obtuse triangle and observed that circumcenter of an obtuse triangle is outside the triangle.

She knew from students' mathematics teacher that students had necessary prerequisite knowledge about triangles to participate in the lesson and class discussion. They knew that any point on the perpendicular bisector of a line segment AB joining Point A to Point B is equidistant from the points A and B. Students have had information about GeoGebra program from previous lesson. This time, students used GeoGebra program by themselves for the first time in the computer lab. The write up problem presented in Figure 4.15

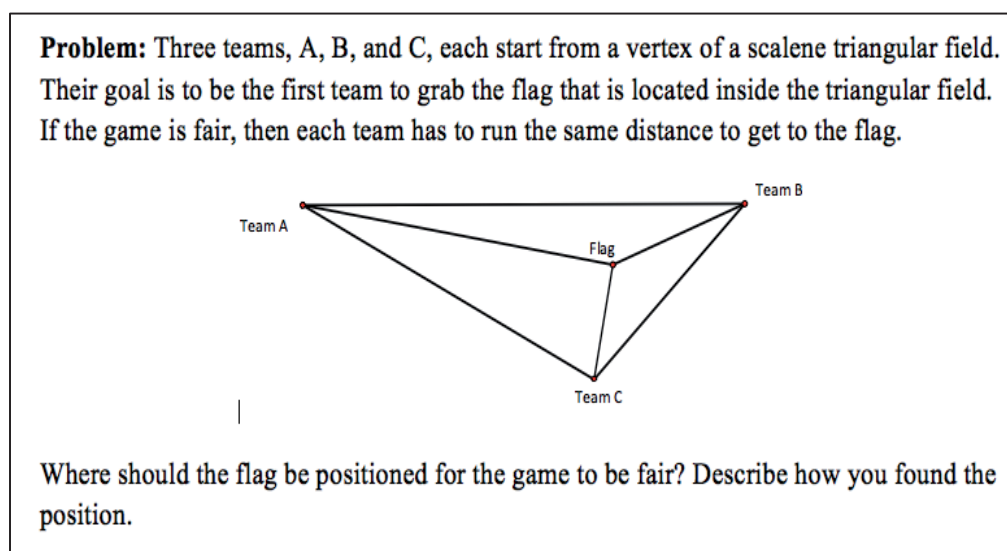


Figure 4.15 The write up problem in ELE 430 course

At the beginning of the lesson, Meltem explained to students the reason why they were in computer lab. She said that they would solve a real life problem with the help of GeoGebra program during the lesson. Then, she reminded students about the GeoGebra program from previous lesson. She also gave them information about its menu related to what they would use while solving the problem. Then, she distributed activity sheets prepared for students to let them know what the problem is and project the problem onto the white board as presented in Figure 4.16.

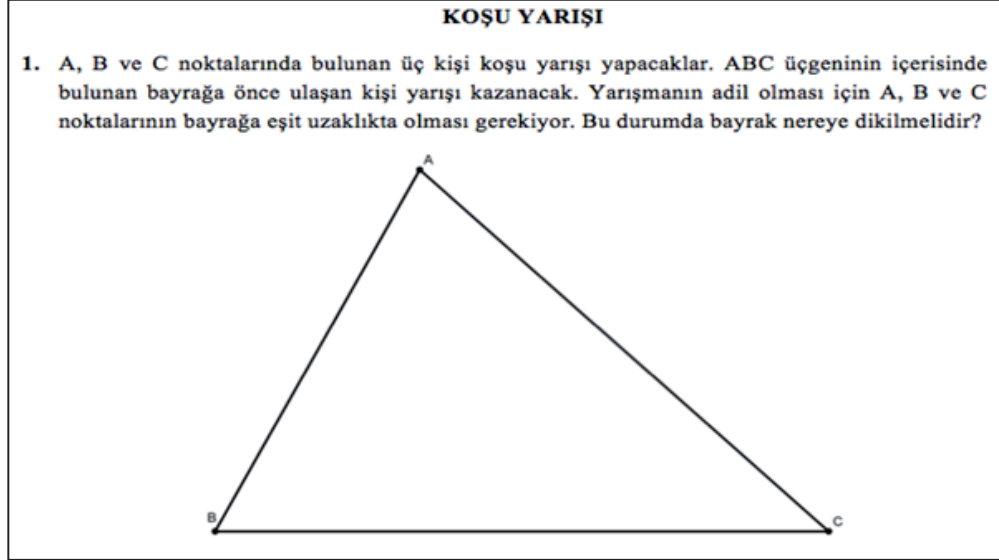


Figure 4.16 Meltem's second problem in second lesson

Meltem gave two minutes for to students to read the problem. Then, she asked students to turn their face to her and explain the problem. She chose one of the volunteer students. Student read the problem then Meltem asked.

*Meltem: Does everybody understand the problem? Do you have any idea about the solution? What are we looking for? [v.02.30-2.35].*

*Student: We are looking for a point in the triangle, which should be equidistant from vertices. [v.02.36-2.40].*

She repeated the student answer and asked whether they have any idea. There was no answer. Then she asked them to open the GeoGebra file on their computer desktop named "ABC". Students click on the file and opened the file and she asked students to click on the checkbox named "deneme" and try to place point D to make three lengths of AD, BD and CD were equal as presented in Figure 4.17.

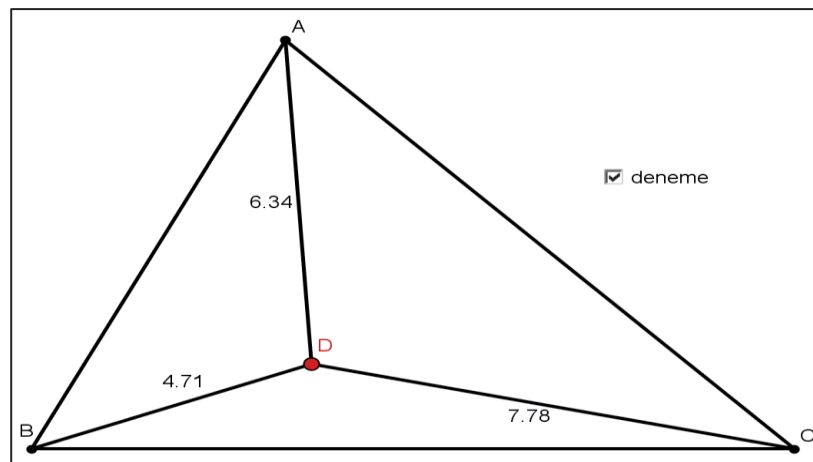


Figure 4.17 Trial file of Meltem's second lesson

Note. English translations of “deneme” is trial.

Students opened the file and gave a try to locate the point D to fix the length of BD, AD and CD up for five minutes. When they move the point D so that they could observe the change in the length of each vertex. Although there were students who very close to locating the correct position, no student found the exact point for circumcenter of a triangle by moving the point. During this time, Meltem asked them if they had any ideas about the solution. One of the students said that;

*Student: As if there is a circle passing through vertexes of triangle and we are looking for center of this circle. [v.10.42-10.50].*

*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: The most important thing is why this point is about there. Of course you can find with the help of GeoGebra where the point is even accidentally. You need to give an explanation. Without mathematical explanation the point is nothing. [v.12.00-13.04].*

There was no solution for the problem. Meltem asked students whether they need a hint. Students said yes. Then, Meltem told students;

*Meltem: Click off the trial check box and open the algebra view in GeoGebra file and find item “q”, under free objects and click on. [v.13.04-13.24].*

This trial in GeoGebra file provided an environment for students to take mathematically meaningful actions on circumcenter of a triangle. Students had an idea about where the circumcenter of a triangle might be deploy.

Then, she showed what she said on the teacher laptop and projected it on the white board. Since she wanted to keep students away from hints, Meltem had to hide hint box in the GeoGebra file. When they clicked on item q, students saw the checkbox named “hint” as presented in Figure 4.18.

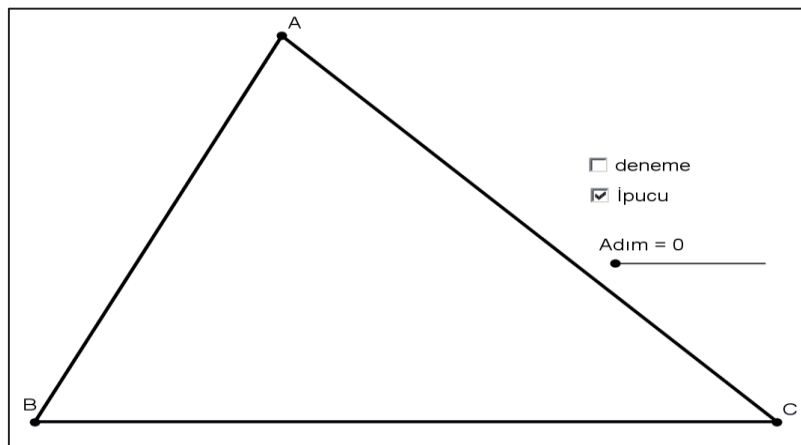


Figure 4.18 Opening the hint box

Note. English translations of “ipucu” is hint and “Adım” is step.

There were six steps in hints box connected with the slider. Step by step students would move the slider and go through the solution of the problem.

*Meltem: May I take your attention here; let's look at the board. To solve the problem first of all 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. [v.13.30-13.45].*

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 [v.13.04-13.24].*

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 4.19.

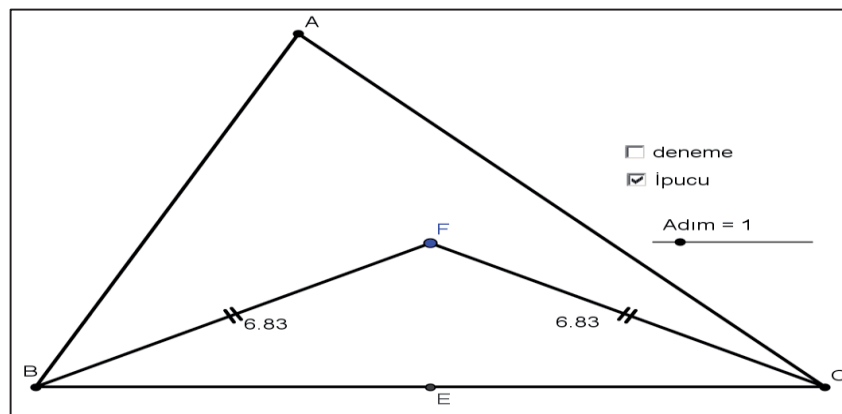


Figure 4.19 First step hint of Meltem's second problem in second lesson

*Meltem: As you said it is an isosceles triangle. Let's move the point F, and tell me what you are observing? [v.14.04-14.15].*

*Student: In spite of the length of the distance from vertex point change, when I move the point F, it is still equidistance. In addition to this point F couldn't be moved right or left, it goes through on the same direction.*

*Meltem: Yes you are right, do you have any idea about its reason?*

*Student: Yeah otherwise, the equality might be unbalanced.*

*Meltem: It is true.[v.16.05-16.11].*

After students answers Meltem asked students to right click on the point F, and chose “Trace On” item and then move the point F again. Students did what she said, and one of the students said that;

*Student: Point F's trace is a perpendicular bisector of BC side of the triangle, and E is the mid point of the BC side*”[v.16.51-17.02] as presented in Figure 4.20.

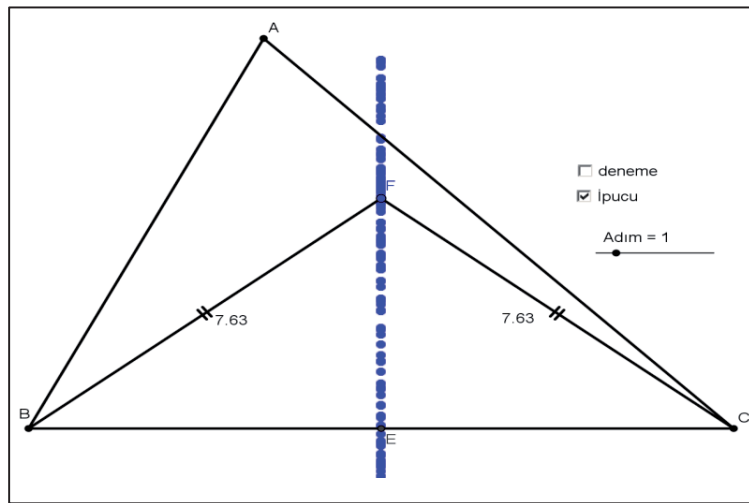


Figure 4.20 Trace on

Meltem asked them to check it by measuring the angle CEF, BEF and lengths BE, EC. Then she measured angles and lengths in Geogebra and asked them measure same elements in their triangle. Students measured same elements in their GeoGebra file and noticed the characteristic of this line. Meltem underlined that they have the lengths BF and CF equal as long as they have point F on the perpendicular bisector of the side BC. Meltem asked students whether there is anyone who wants to share opinion about the problem. Students said no and she went on Step 2. She asked students move the slider one step further as presented in Figure 4.21.



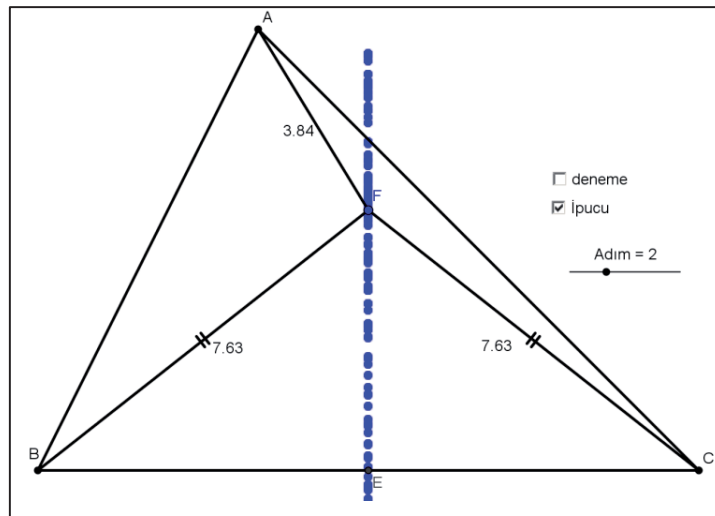


Figure 4.21 Second step hint of Meltem's second problem in second lesson

When students move the slider one step further, AF segment was appeared.

*Meltem: Look at the point, is it ok now? Did we found the point that we are looking for? [v.22.30-22.43].*

*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 [v.26.40-26.52].*

*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 in Figure 4.22.

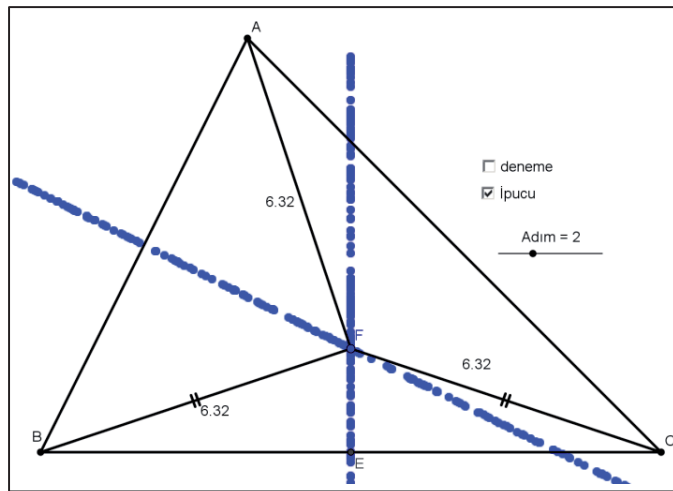


Figure 4.22 Point found by student

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.

In this part of the lesson, Meltem used pedagogical knowledge to be a guide for students to solve the problem. Students noticed the logic behind the constructing a circumcenter of a triangle.

Then two of the students proposed that they could solve the problem by paper folding. They cut a triangle from a paper and found the mid point of the each three sides, and then they folded the paper from each midpoint perpendicularly. This intersect point of the three perpendicular segment was the point that they were looking for. After, confirming students' answer, they were asked to explain the reason why they found midpoints of each side and fold perpendicularly in detail to justify their solution. However students said that they learned by this way during their lesson with their teacher instead of explaining their reasoning.

The bell rang for a 10 minutes break time. During this time 18 of the students kept working in the computer lab and checked the GeoGebra menu out. After break time Meltem went on her lesson with Step 3.

Then she told students to move on to Step 3 as presented in Figure 4.23.

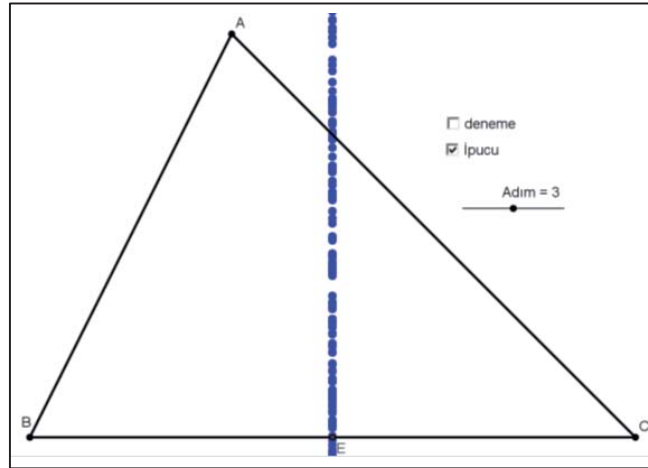


Figure 4.23 Third step hint of Meltem's second problem in second lesson

Step 3 was a gateway to Step 4 BF, CF and AF disappeared. Then Meltem asked students to move slider to Step 4. When students move the slider Step 4, they saw G, mid point of AC line, and two equal lines BI and AI was presented in Figure 4.24.

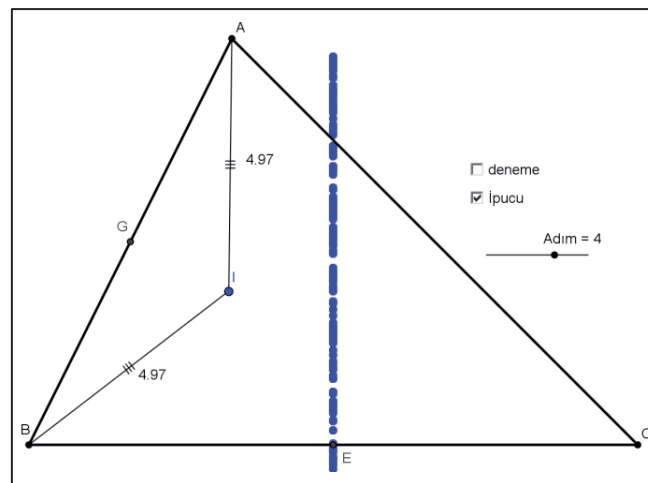


Figure 4.24 Fourth step hint of Meltem's second problem in second lesson

Meltem asked similar questions as she did in Step 1, this time students traced on point I as presented in Figure 4.25.

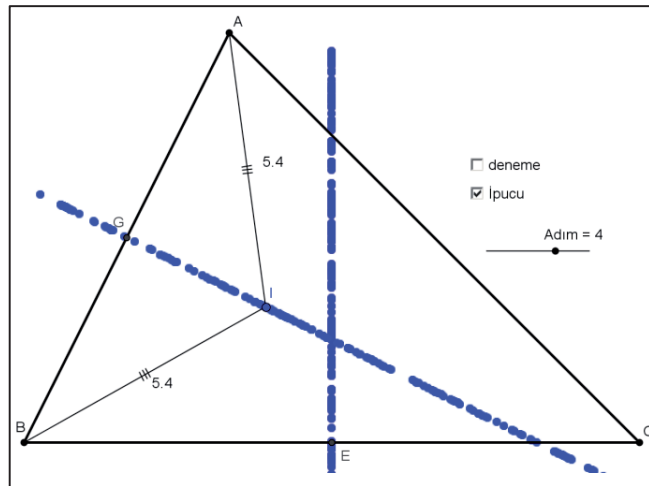


Figure 4.25 Second trace on

Meltem had students moved on to Step 5. When students moved the slider, they saw point H as presented in Figure 4.26.

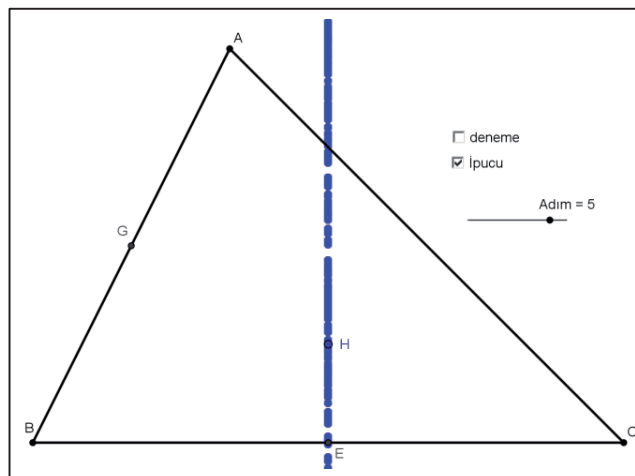


Figure 4.26 Fifth step hint of Meltem's second problem in second lesson

Meltem asked students to connect point G and point H with the help of GeoGebra menu, “line through two points.” Students chose “line through two point” from menu and draw a line between point G and point H as presented in Figure 4.27. Then Meltem said that;

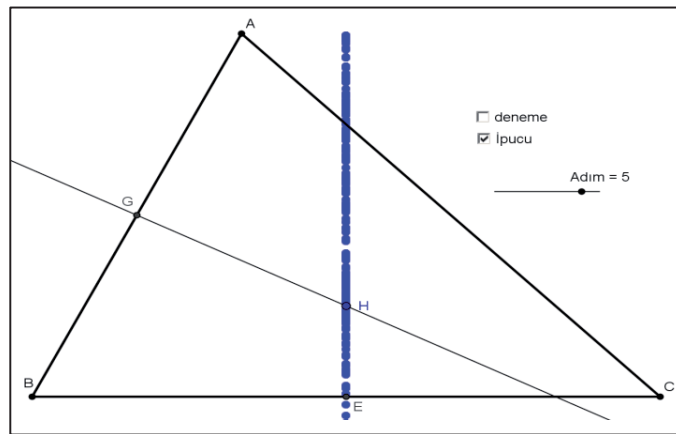


Figure 4.27 Line through two points

*Meltem: We found the intersection point of perpendicular bisectors, this point is circumcenter of this triangle.”[v.08.03-08.10].*

Students realized that point H is circumcenter of the triangle ABC. Then Meltem asked students to move the slider Step 6 as stated in Figure 4.28.

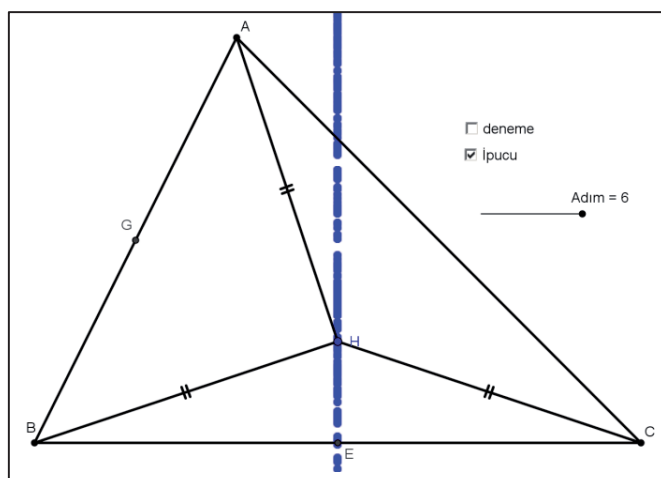


Figure 4.28 Sixth step hint of Meltem's second problem in second lesson

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. [v.16.51-17.02].*

*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 4.29.

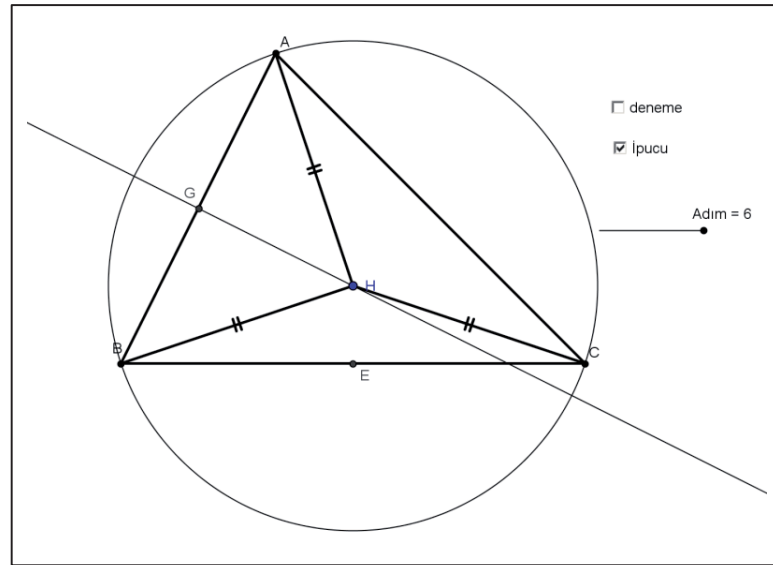


Figure 4.29 Circumcircle of the triangle

Then, Meltem asked students to write the solution of the problem on their activity sheet in detail. Technology usage was aligned with the lesson objectives. GeoGebra technology procedures were concentrated on circumcenter of a triangle. In the lesson, GeoGebra program used by students in the larger part of the class time in order to explore and experiment with it for new knowledge and practice.

After that, to assess students understanding, Meltem asked students to open the second file named "KLM" and read the second problem. One of the students read the problem loudly. Second problem was the same as the first problem, except for the type of the triangle. This time triangle was obtuse. In GeoGebra file there was an obtuse triangle. Meltem gave students five minutes to solve the problem via GeoGebra. Students worked with GeoGebra file on their computer and wrote their answers onto the activity sheets. One of the students complained from there were no hints in the GeoGebra file. Then Meltem asked students;

*Meltem: What we need to do first?" [v.16.51-17.02]. She let one of the volunteer students to share her solution with the class.*

*Student: We need to find mid point of the each side. Then draw perpendicular bisectors of them. At the end we need to find intersect point of the perpendicular bisectors. Intersect point is the circumcenter of the triangle.*

Meltem construct all steps via GeoGebra by projecting on the board and asked students to construct in their computer at the same time. The final figure is presented in Figure 4.30.

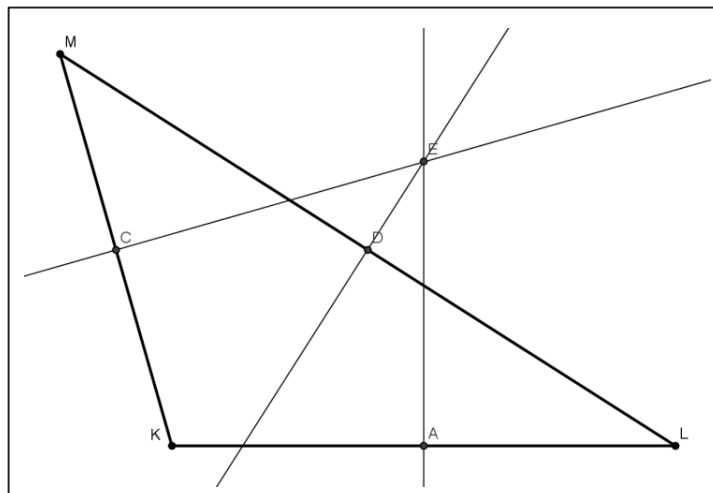


Figure 4.30 Circumcenter of obtuse the triangle

Then she asked;

*Meltem: What is the difference between in these two cases?*

*Student: The flag in the first question was placed inside the triangle, while second question was placed outside the triangle.*

*Meltem: What was the reason?*

*Student: the type of the triangle. Students concluded that circumcenter of an acute triangle is inside the triangle, while circumcenter of an obtuse triangle is outside. [v.23.01-24.13].*

In the closing part, Meltem asked students open the last GeoGebra activity file named “3” as presented in Figure 4.31. She underline that D was the circumcenter of the triangle ABC. She had students moved the point D and observe the difference.



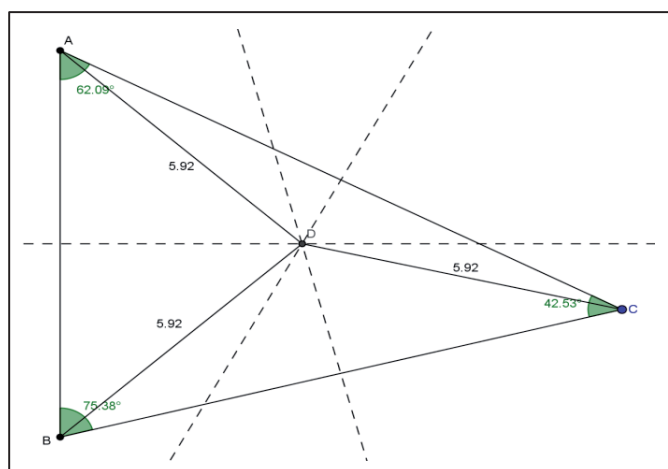


Figure 4.31 Circumcenter of an acute triangle is inside the triangle

And she repeated the rule “circumcenter of an acute triangle is inside the triangle” by displaying with the help of GeoGebra. Then Meltem asked  
*Meltem: What about right triangle?”*

Students moved the one the vertex points to fit it 90 degree as presented in Figure 4.32.

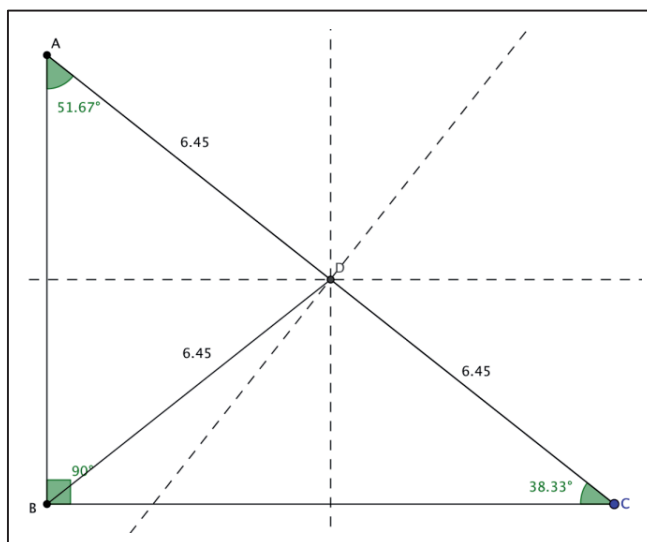


Figure 4.32 Circumcenter of a right triangle is on its hypotenuse

Students observed that circumcenter of a right triangle is on its hypotenuse. Then Meltem asked students to move the vertex point and made an obtuse triangle and observe the circumcenter as presented in Figure 4.33.

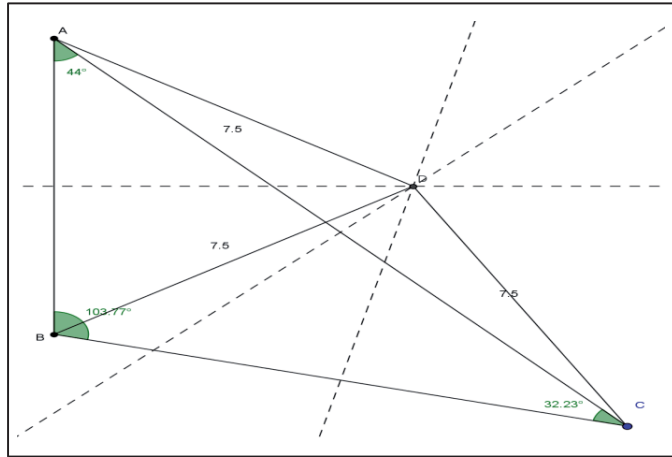


Figure 4.33 Circumcenter of an obtuse triangle is outside the triangle

Students concluded that circumcenter of an obtuse triangle is outside the triangle. At the end of the lesson Meltem asked students whether they have any question about the lesson that they did not understand. Students said no and she finished the lesson.

Educational technology was used effectively in this lesson. Students made experiment via GeoGebra program to find the circumcenter of a triangle. This experience helped them to have an idea about the circumcenter of a triangle.

#### 4.1.1.2.1 Student Reflection

At the end of the lesson, Meltem asked students to write a reflection paper in order to evaluate the lesson from students' point of view. The questions for this paper were the same as in previous lesson with an additional question. This question was added to have

students' preferences being in the computer lab and classroom while working GeoGebra program. The question was;

- Do you prefer being in the classroom instead of being in the computer lab while working with GeoGebra program?

During the last ten minutes of the class time, students were asked to write their reflections to the lesson to provide feedback about the lesson implementation to Meltem. She projected these set of reflective questions on the board to pave the way for reflection paper. Seventeen out of 23 students wrote their comments about the lesson. Six of the students didn't want to share their opinion about the lesson. 14 out of 17 student comments about the lesson were favorable. According to their answers, students were pleased to learn circumcenter of the triangle via GeoGebra program in lab environment. Seven of the students, appreciated hints to solve the problem step by step. Three of the students complained from the lesson, since he bored. He stated that "we solved only one problem during the lesson. It was boring." Another student's comment was "since, there were not enough computers in the lab, I had a problem with my friend in terms of usage of the GeoGebra." One of the students comments was "I couldn't understand the solution of the problem I confused.

In this lesson, students made an experiment via GeoGebra program to discover the circumcenter of a triangle and construct a relationship; circumcenter of an acute triangle is inside the triangle, circumcenter of a right triangle is on its hypotenuse and circumcenter of an obtuse triangle is outside the triangle via GeoGebra program. This time lesson was implemented in computer lab to have students make an examination via trial GeoGebra task and discover the relationship on their own. As they stated in reflection papers, in general students appreciated having experience with GeoGebra program, even if some of the students complain from not having enough computers for each student.

#### 4.1.1.2.2 Meltem's Second Lesson Performance

In second lesson, Meltem's performance for the C1 was consistent with the exploring level. Meltem's level for C1 increased from adapting level to exploring level. C1 mainly related to the purposes of integrating technology in teaching mathematics. The purpose of using educational technology in the second lesson was to have students experience with mathematical discoveries via GeoGebra program. In this lesson Meltem modeled a problem and prepared hints for students to assist them in the solution process. In addition she constructed two trial activity via GeoGebra to have students explore and make conjecture about the geometry concepts. In exploring level *larger part of technology is used by students who explore and experiment with it for new knowledge and for practice*. At the beginning of the lesson, Meltem gave students a problem task. In the problem there were three teams whose goal was to be the first team to grab the flag that is located inside the triangular field. Their started point was three vertexes points of the triangle. The problem required students to find circumcenter of a triangle. Students explored the exact location for the flag in a triangular field. To provide this opportunity to the students, Meltem generated a trial file via GeoGebra for students to explore and make conjecture about the exact place of the circumcenter of a triangle. Via this file, students explored the exact place for the flag in a triangular field. Students explored for a while and then they need hint to go one step further in solution process of the problem. Meltem had already constructed six steps hints connecting with the slider in GeoGebra file and she shared them step-by-step. She had constructed one more Geogebra file to have student generalize the rule to find a circumcenter of any kind of triangle. The usage of educational technology was crucial in this lesson. Without technology it was also possible to find a circumcenter of a triangle with paper-based. The advantage of technology was providing students an environment to explore the location of the circumcenter of a triangle via dynamic point and text box, which includes the measures of the distance of the points to the vertexes of the triangle. Meltem could

also give students hints verbally, however, since hints included hide the object, trace on the geometrical concepts etc. this wasn't possible to give that hints in this way.

Meltem's performance for the C2 was consistent with the adapting level. Meltem's level for the C2 increased from accepting level to adapting level. C2 mainly related to the PSTs' knowledge of students' understandings, thinking, and learning in technology-based mathematics lesson. In the lesson, Meltem focused on students' thinking of how to find circumcenter of a triangle via GeoGebra explorations. Meltem divided solution of the problem into the steps and created a hint for each step to assist students in solution of the problem. In adapting level, *teacher focuses on students' thinking of mathematics while students are using technology on their own – both for learning new knowledge and review of prior knowledge*. Design of the lesson was appropriate for students' independent explorations and technology frequently used by students. In this lesson firstly students explored the circumcenter of a triangle to discover the exact place for circumcenter of a triangle on their own via trial GeoGebra file in computer lab. Then she gave hints step by step. In first step the hint was isosceles triangle with a dynamic top point. With the help of this dynamic point, students observed that top point of this triangle always equidistant from each vertex. She had hidden the height of the isosceles triangle as well, after students noticed that point was on the height of the triangle, they confirmed their thinking by making trace on this point. In the last step, students saw the point they were looking for was intersect point of three perpendicular lines of each sides. After discussing each step, students went on to next step to find the circumcenter of a triangle. To generalize the rule to any kind of triangle Meltem constructed one more trial file which help students notice the circumcenter of an acute triangle is inside the triangle, circumcenter of a right triangle is on its hypotenuse; circumcenter of an obtuse triangle is outside the triangle via dynamic vertex points of triangle which makes it acute, right and obtuse. The hints and trial activities were applicable for these students. The hints were very helpful for students in solution process. Trial files help students notice the location of the circumcenter of a triangle and provided a dynamic

environment for students to explore the location of the circumcenter of a triangle and helped them generalize the rule for any kind of triangle. The questions were so appropriate for students' level that most of the students could answer. Instead of observing teacher demonstrations, students actually did mathematics in this lesson.

Meltem's performance for the C3 was consistent with the exploring level. Meltem's level for C3 remained at the exploring level. C3 mainly related to the PSTs' knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics. The lesson objectives were; the students will be able to construct circumcenter of a triangle and the student will be able to construct the relationship; circumcenter of an acute triangle is inside the triangle, circumcenter of a right triangle is on its hypotenuse; circumcenter of an obtuse triangle is outside the triangle. It was a basic and important geometry content in the curriculum. In exploring level, *students are given problem-solving tasks with technology and are asked to expand math ideas on the basis of technology explorations. Technology usage was aligned with curriculum goals.* There was a sequence between technology-based activities. At the beginning of the lesson, Meltem gave students a problem task. The task constructed by Meltem for the solution of the problem via GeoGebra was well structured. She gave students the starter trial activity, to give a clue about the solution of the problem. Then she gave the hints one by one to assist students in solution process. First hint was related to students' previous knowledge which was isosceles triangle. With the help of dynamic top point of isosceles triangle, students noticed that this point always equidistant from each vertex. After students noticed that point was on the height of the triangle, they confirmed their thinking by making trace on this point. At the end students saw the point they were looking for, which was intersect point of three perpendicular lines of each sides. Then she gave students the second trial activity, to have them generalize this rule to any kind of triangle. Second trial file help students notice the relationship; between type of triangle and location of the circumcenter which was circumcenter of an acute

triangle is inside the triangle, circumcenter of a right triangle is on its hypotenuse; circumcenter of an obtuse triangle is outside the triangle.

Meltem's performance for the C4 was consistent with the exploring level. Meltem's level for the C4 increased from adapting level to exploring level. C4 mainly related to the knowledge of instructional strategies and representations for teaching and learning mathematics via technology. In exploring level, *teacher uses various instructional strategies (deductive and inductive) and focuses on students thinking about mathematics*. In this lesson, Meltem used inductive instructional strategy to have students make judgments about the geometric rule. In the lesson, Meltem served as a guide of student learning with technology in computer lab. She 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. This time she gave enough time to students to describe their opinions. In addition, she had prepared worksheets for students to help them in following the questions. In this lesson Meltem used technology as a tool to give students directions when they need to solve the problem.

#### **4.1.1.2.3 Post Interview II**

After implementing the second lesson, Meltem was interviewed to reflect on her lesson implementation. During this interview she asked to share her opinions about the lesson implementation. Her performance to use educational technology in teaching were criticized by themselves in terms of purpose of the activity (cognitively challenging), the role of the teacher (a guide and help students focus on reasoning), and role of the

questions (to led students explore mathematical concepts, discover relationship between mathematical concepts).

In her opinion, the technology usage was very essential in this lesson as well. Without this technology it was still possible to give hints to the students verbally and visually. However, the advantage of technology was providing students a chance to observe the motion dynamically and make an interpretation about the relationship between geometric concepts. During the interview, she stated that it was a problem-solving lesson and asking questions to help students make reasoning about the place of circumcenter of a triangle was the biggest concern of the Meltem. Educational technology needed to be integrated into mathematics to assist students via hints and challenge them via questions. She reported on the main issues that have been discussed in the interview were;

actually, it was more difficult than I thought for students to complete this task. In the lesson I let students actively participate in the lesson with the help of hints. They had a chance to explain their strategies, and conjectures by giving evidences and test their own mathematical ideas with the help of GeoGebra. I was a resource person in the class. I asked questions and I tried to listen ideas from each student. In general my lesson was implemented in consistent with what I planned initially. Only difference was skipping some of the questions, since students' need more time than I planned.

#### **4.1.1.3 Findings of Meltem's Third Implementation**

Meltem implemented her third lesson via GeoGebra program with 27 eighth grade students, who were the same students in previous lesson, in the classroom. Classroom includes projector and board to display GeoGebra file to the class. Meltem used a laptop to project her GeoGebra file onto the white board. The technology-based activities that she prepared for the lesson were her final project for ELE 430 course. She was familiar with the students and classroom environment, since she had already implement her first and second lesson with them and she has also been in this class for observation in the



context of field experience course. The subject of the lesson was circle. Lesson objective were; students realized the ratio between central angle and an inscribed angle that trace the same arc is two, students solve the real life problems related to relationship between central angle and its arc and students draw a circle when only three points to pass through are given. Meltem decided lesson objectives by herself and mentor teacher confirmed that subject is available to teach for this lesson. The teaching method that she planned to use was discussion and problem solving. The aim of the first technology-based was noticed students the ratio between central angle and an inscribed angle that traced the same arc, the aim of second one was challenge students to find an equation between angle of rotation and distance traveled by starting point and in last activity, the aim of last one was drawn students a circle passing through any three points. Her goal to use technology in this lesson was to have students observe a dynamic mechanism constructed via GeoGebra and make interpretations about the relationship between angle of rotation and distance traveled by starting point. Meltem planned to be guides in the lesson to have students reach the lesson objectives. Meltem felt ready to teach and had no concern about lesson implementation before the lesson. The duration of the lesson was 40 minutes.

To implement lesson, Meltem constructed three GeoGebra files for the lesson. In the first file, she had constructed a central angle and an inscribed angle that trace the same arc and wrote an equation to display the ratio between them. It was possible to change the angles dynamically; therefore, students had an opportunity to see the ratio always two between these angles. In the second file she simulated a transportation system problem in order to pull a box up. When the pulley was rotated by angle controlled by the slider, the box was lifted. With the help of this file students observed when the pulley is  $360^\circ$  rotated, box is lifted  $2\pi r$  units up and they conclude that when the pulley is rotated by  $\alpha$  degrees, the rope is pulled  $\frac{\alpha}{360^\circ} \times 2\pi r$  units up. In the third file she modeled second problem, in this problem students were asked to draw a circle when only three points to pass through are given. In the third file, there were six step hints to

have students solve the problem. To give these hints to the students, a single slider with six intervals was designed by her. Each point on the slider corresponded to a new step in the problem. During the lesson, students solved the problem by using these hints. Detailed information is given in description part.

She knew from students' mathematics teacher that students had necessary pre knowledge about circle to participate in the class discussion. Students have had information about GeoGebra program from previous lessons. Portions of the lesson plan are included in the description, but were not implemented due to a time limitation. These are included here because they provide insight into Meltem's knowledge of educational technology, pedagogy and content.

At the beginning of the lesson she informed students that lesson topic was circle. She asked students to warm them up to the lesson;

*Meltem: What is circle? [v.00.15-00.20].*

*Students: A round.*

*Meltem: What are the basic elements of circle.*

Students said the basic elements of circle in choral response. She listed the elements of a circle verbally that student referred, center, radius, diameter.

*Meltem: How can you draw a circle?*

*Students: With compass. [v.01.25-01.35].*

*Meltem: Can you explain it?*

*Student: I chose a center point first, and I decide the length of the radius then I turned it  $360^\circ$*

*Meltem: Why you use compass?*

*Students: Because to draw a perfect circle I have to keep radius constant. [v.01.42-01.47].*

Meltem asked students to state the definition of a circle. She let them share their ideas with the class, and discuss. At the end students came up with the definition of circle.

*Meltem: So we can define circle as “consists of points equidistant from a fixed point”. Fixed point is the center of the circle, right?*

*Students: Right.*

Then she asked one of the students to come to the laptop and draw a circle via GeoGebra. She chose one of the volunteer students to draw the circle. When he came, Meltem asked him to choose a center point and any point that he wanted to lie on the circle. Then student chose two points; A and B in the GeoGebra file.

*Meltem: What do we need to draw a circle now? [v.02.53-02.58].*

*Student: We need to rotate point B  $360^0$  around point A.*

*Meltem: Lets do this with the help of GeoGebra.*

Then Meltem helped students to create an angle slider between 0 and  $360^0$ , its name was  $\alpha$  and she chose “rotate object around point by angle” from the menu then she selected point B to rotate center point A and entered the  $\alpha$  as an angle. After that she moved the slider and display rotation of the point B to the students. When she made point B trace on, circle appeared. She went on asking;

*Meltem: What kind of angles can we define on the circle?[v.05.40-05.46].*

*Students: Central and inscribed angle.*

She asked a volunteer student to create a central angle and an inscribed angle that trace the same arc via GeoGebra. One of the students came and drew the angles. Then she asked student to measure two angles by using GeoGebra. Students measured the angles and observed the relationship between central angle and an inscribed angle by changing the measures as presented in Figure 4.34.

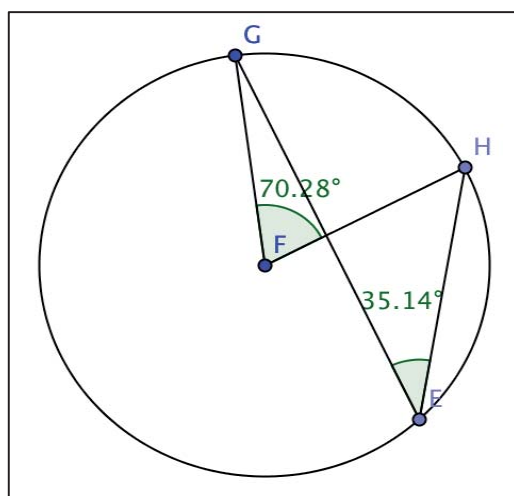


Figure 4.34 Central angle and inscribed angle

Students concluded that central angle is twice the measure of the inscribed angle. In the lesson plan, she had planned to show this ratio via GeoGebra. For this aim she had prepared a GeoGebra file as presented in Figure 4.35, however she didn't display this file to the students.

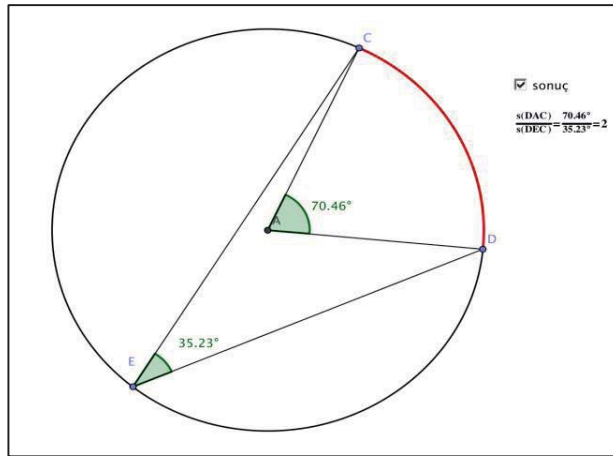


Figure 4.35 The ratio of central angle on inscribed angle

She went on asking about the other elements of triangle.

*Meltem: What were the other elements of circle? [v.11.49-11.55].*

*Student: Area, perimeter*

The purpose of the activity was to have students realized the ratio between central angle and an inscribed angle that traced the same arc is 2. In the lesson, she used concrete materials via GeoGebra to help students visualize ratio between central angle and an inscribed angle. She engaged students into the class discussions. She encouraged students to share their ideas about the solution of the problem and she helped them verbalize their ideas by means of asking several questions and making restatements. Finally students noticed the ratio was two.

To display the second problem, she opened the second GeoGebra file named “transportation system”. To begin with, she asked students to observe what was happening when the pulley was rotated by angle controlled by the slider as presented in Figure 4.36.

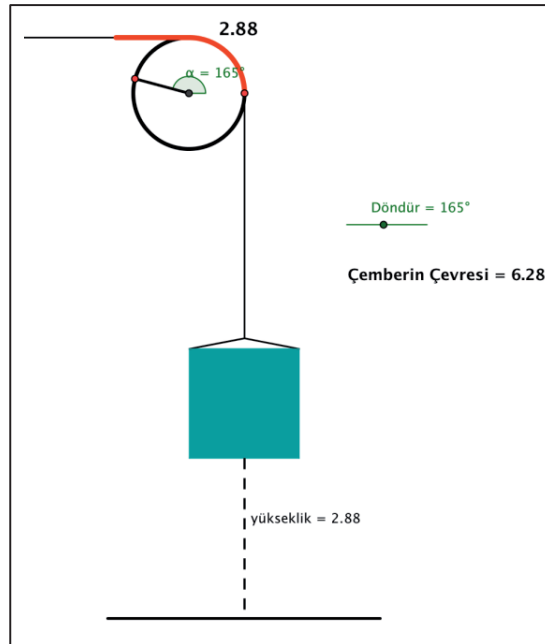


Figure 4.36 Rotating pulley

Note. The English translation of “Döndür” is rotate, “Çemberin Çevresi” is perimeter of circle, “yükseklik” is height.

*Meltem: What kind of system is this? [v.12.04-12.44].*

*Students: Lifting load.*

*Meltem: Right we want to lift the box up, from where do you think, do I need to drive the system up?*

*Student: From the top point...*

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. [v.12.48-12.53].*

*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  $360^\circ$  via GeoGebra.

*Student: Circumference of the pulley.*

*Meltem: Well, If I rotate the pulley  $180^\circ$ ?*

*Student: Then it goes up half of the circumference of the pulley.*

Then she asked students find the ratio between angle of rotation and distance traveled by starting point. After that she opened the spreadsheet view of GeoGebra and had students saw the table as presented in Figure 4.37 In this table the first column was the angle of rotation and the second column was the distance traveled by starting point corresponding to that rotation angle.

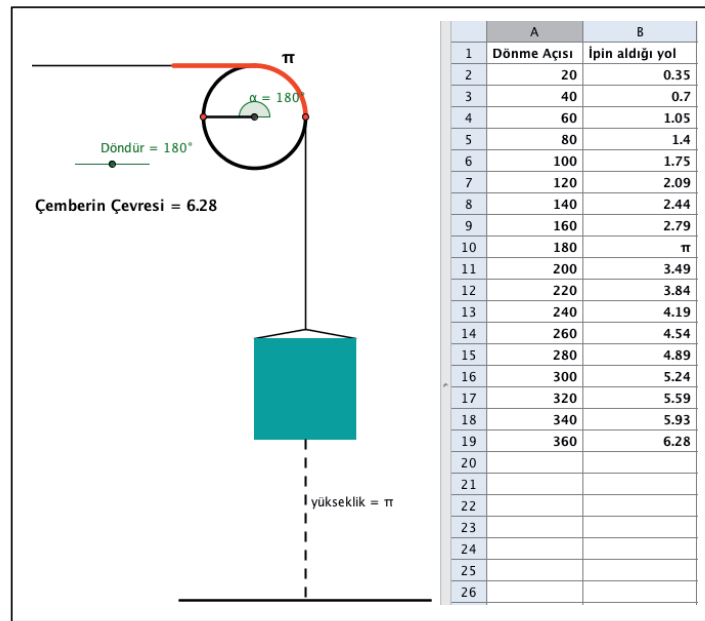


Figure 4.37 Angle of rotation and distance traveled by starting point

She gave two minutes students to analyze the table and wanted them to make a generalization about this relationship. At the end students concluded that: when the pulley is rotated by  $\alpha$  degree, the rope is pulled  $\frac{\alpha}{360^\circ} \times 2\pi r$  units up.

In this activity, students were challenged to find an equation between angle of rotation and distance traveled by starting point. With the use of GeoGebra program 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.

Then she went on with the last activity. She asked students to choose three non-collinear points on their blank sheet and try to draw a circle passing through those points.

She had students work individually for 4-5 minutes. Then let them share their ideas with the class to discuss. At that time she opened the GeoGebra file named “circle” as presented in Figure 4.38.



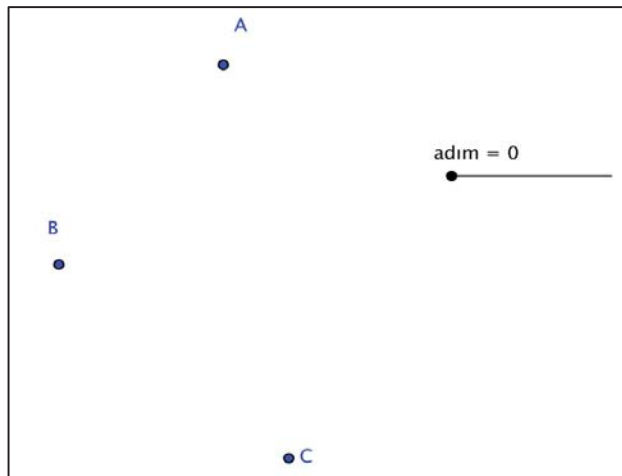


Figure 4.38 Three points

*Students: We can try to draw a circle that passes these three points.*

*Meltem: To where do you place the center of the circle? [v.25.00-25.07].*

*Meltem: Do you need hint?*

*Students: Yes.*

Then, she moved the slider to Step 1 as presented in Figure 4.39

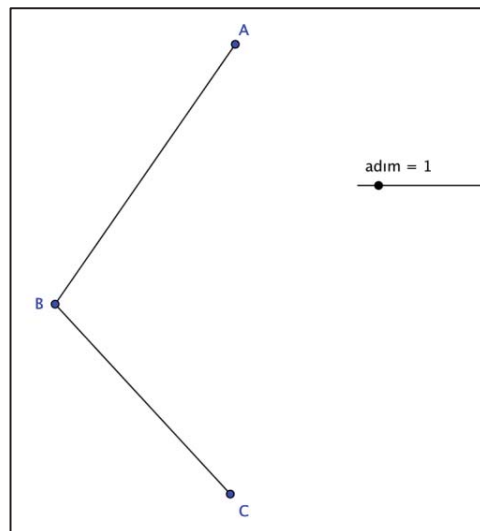


Figure 4.39 Chords

She asked students;

*Meltem: If there were a circle passing through point A, B and C, which elements of the circle would be AB and BC line segments do you think? [v.25.15-25.19].*

*Student: Two chords.*

*Meltem: Do you have an idea about center of the circle now?*

*Student: We can construct a triangle ABC and find the symmetrical point of B according to the AC segment.*

*Meltem: Do you want to come and check your idea via GeoGebra?*

*Student: Yes.*

Students come near to the laptop and draw a line from point A to C and find the symmetrical point of B according to the AC segment and connected to each point and made a rectangular. After that, he constructed the diagonals and found the point of intersection. At the end he claimed that this intersects point was the center of the circle. He drew a circle as presented in the Figure 4.40. However circle didn't pass through points A, B and C.

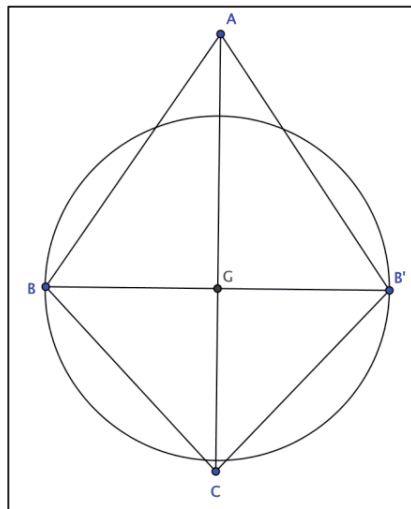


Figure 4.40 Student's incorrect reasoning

*Meltem: We have three points A, B, C and we want to find a point that is equidistant from each point. If you think A, B, C as a triangle how can we find the point that we are looking for?*

*Student: We can construct a triangle with points A, B and C and then as we did previous lesson we can find the perpendicular bisector of each segment and find the circumcenter of the triangle. That point is the center of the triangle. For this case I think center point is out of the triangle, I guess.*

*Meltem: Let's come and construct your idea.*

Student came and constructed the circle with the help of Meltem as presented in Figure 4.41.

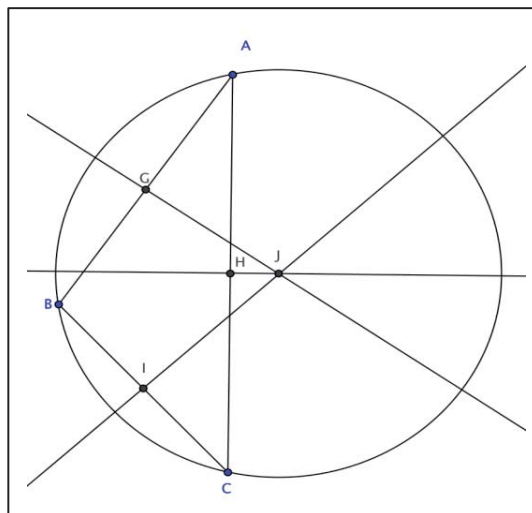


Figure 4.41 Student's right reasoning

Meltem encouraged students to share their ideas about the solution of the problem and she helped them verbalize their ideas by means of asking several questions and making restatements. The technology-based activities she constructed offered opportunities for discussion to take place between students and students, and students and teacher.

The class time was about the up therefore Meltem repeated what student said and confirmed his solution. Because of time limitation students didn't write answer to reflective questions. Then Meltem finished the lesson. In lesson plan she has another way to display solution of the problem. However she couldn't share it with students because of time limitation. At the Step 2 the mid point of the two chords; D and E were

highlighted. After that, at the Step 3, perpendicular bisectors of the two chords were drawn as presented in Figure 4.42.

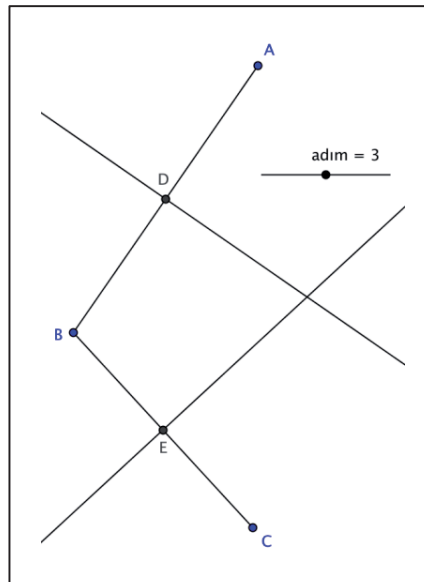


Figure 4.42 Third step hint of Meltem's third problem in third lesson

At Step 4 equal lengths AF, BF and at Step 5 CF were appeared to show students F was equidistant from points A, B and C as presented in Figure 4.43. To help them understand that F is the center of the circle.

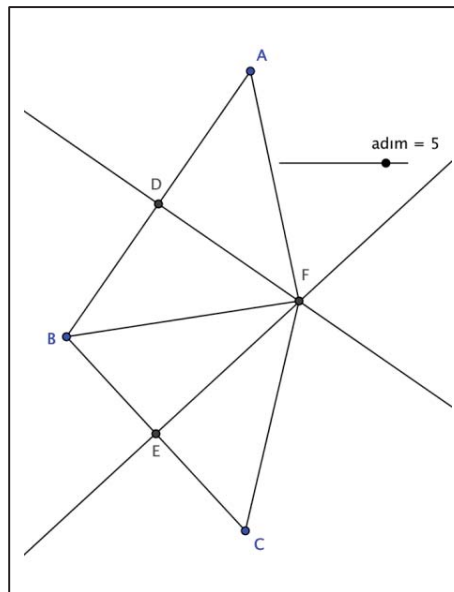


Figure 4.43 Fifth step hint of Meltem's third problem in third lesson

At the Step 6 there was a  $360^\circ$  rotation around point F via appearing angle slider  $\alpha$  as presented in Figure 4.44.

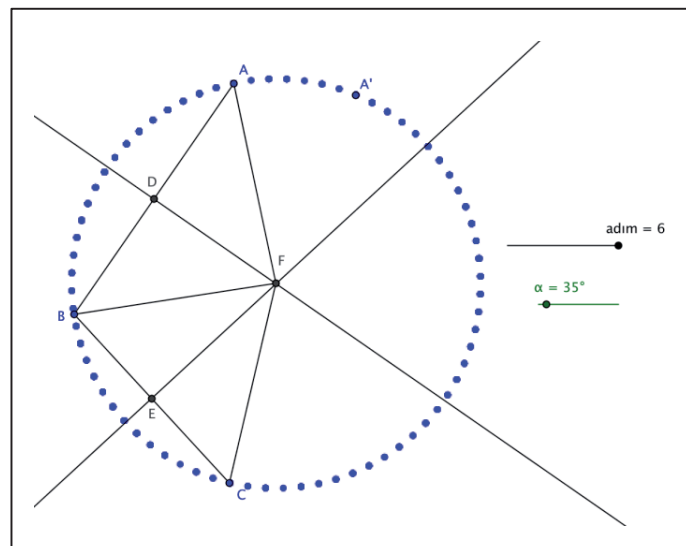


Figure 4.44 Sixth step hint of Meltem's third problem in third lesson

With this problem students were challenged to find a center point, which was equidistance from each points. During the activity, it is aimed to expanded math ideas on the basis of GeoGebra technology explorations. Students were convinced why the central point should be the equidistance from each point on their own effort. This is the end of the lesson. Typically the students had time to write a reflection papers, however this time there was not enough time at the end of the lesson, students did not answer reflective questions.

#### **4.1.1.3.1 Meltem's Third Lesson Performance**

In the third lesson, Meltem's performance for the C1 was consistent with the advancing level. Meltem's level for the C1 increased from exploring level to advancing level. Advancing level is the fifth and highest level to use educational technology in teaching. C1 mainly related to the purposes of integrating technology in teaching mathematics. For this lesson, Meltem prepared three technology activities. 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. *In advancing level technology tasks provide students with deeper conceptual understanding of mathematics and its processes.* The aim of the first activity was to have students noticed the ratio between central angle and an inscribed angle. By dragging the dynamic point on the circle, students observe the ratio between central angle and an inscribed angle that traced the same arc is two. Dynamic visualization of this ratio displayed students that this ratio is always constant. In the second file Meltem constructed a simulation of transportation system to pull a box up. 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. The aim of the second 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  $360^\circ$  rotated, box is lifted  $2\pi r$  units up and they concluded in the discussion that when the pulley is rotated by  $\alpha$  degrees, the rope is pulled  $\frac{\alpha}{360^\circ} \times 2\pi r$  units up. In order to support students to interpret this equation, 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. In the last activity, students were given a problem task with GeoGebra program. Students were asked to draw a circle passing through any three points. With this problem students were challenged to find a center point, which was equidistance from each points. To help students in solution process, Meltem constructed six steps hints via GeoGebra program. The aim of the hints was to encourage students to answer the questions. She gave hints step-by-step via GeoGebra program and students made a connection between previous problem solved in the second lesson and solved the problem. Without educational technology it would be more difficult to display relationships between geometrical concepts in a dynamic way and challenge students via hints.

Meltem's performance for the C2 was consistent with the exploring level. Meltem's level for the C2 increased from adapting level to exploring level. C2 mainly related to the PSTs' knowledge of students' understandings, thinking, and learning in technology-based mathematics lesson. 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. *In exploring level, a document provides an environment for students to deliberately take mathematically meaningful actions on objects.* In all three GeoGebra activities there was an action that students could observe the mathematical consequences. Meltem encouraged students to share their ideas about their observation. During this time she helped students verbalize their ideas by means of asking several questions and making restatements. Her focus was challenge students

cognitively for conceptual understanding. However, not all of the students were actively engaged into the class discussion and posed their ideas. 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.

Meltem's performance for the C3 was consistent with the advancing level. Meltem's level for C3 increased from exploring level to advancing level. C3 mainly related to the PSTs' knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics. In advancing level, *teacher uses technology in a fully constructive way, including tasks for development of higher-level thinking and deepening understanding of mathematics concepts. Technology is strongly aligned with curriculum goals. Teacher chooses essential topics of school mathematics curricula. Technology usage is effective for the chosen curriculum topics.* In the third lesson, Meltem used educational technology to have students make judgments about the geometrical rules. The activities she construct offered opportunities for "math talk" to take place between students and students, and students and teacher. In the lesson, some of the students could explore the relationship between geometrical concepts and test their conjectures via GeoGebra program to reach the lesson objectives. Technology usage was strongly aligned with the lesson objectives. However there were too many lesson objectives to cover in a single lesson. The first lesson objective was students will be able to notice the ratio between central angle and an inscribed angle. In the first activity, students were challenged to find a ratio between central angle and an inscribed angle. Meltem used technology in a constructive way, including tasks for deepening understanding of mathematics concepts. The second lesson objective was students will be able to notice the relationship between angle of rotation and distance traveled by starting point in a pulley system. In the second activity, 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. The third lesson objective was students will be able to solve problems using definition of a circle. Specifically students drew a circle when only three points to pass through are given. In the third activity, students were challenged to find a center point, which was equidistance from each point. It is aimed with these activities was to expanded math ideas on the basis of GeoGebra technology explorations. In this lesson Meltem choose essential topics of school mathematics curricula. However, there was a time limitation to implement these three activities in a lesson, therefore students couldn't have equal chance to explore mathematical concepts via GeoGebra and discover the rules by themselves. Since each student didn't have the equal chance, they couldn't reach this objective at the same level.

Meltem's performance for the C4 was consistent with the exploring level. Meltem's level for the C4 remained at the exploring level. C4 mainly related to the knowledge of instructional strategies and representations for teaching and learning mathematics via technology. In exploring level, *teacher focuses on students thinking about mathematics. Technological activity document is built around learning objects and must explicitly promote student reflection – especially the posing of questions for sense making.* In this lesson, the role of the Meltem was a guide to promote students' reactions and making sense with mathematical concepts via GeoGebra. Meltem used discussion and problem solving teaching methods. Meltem used technology to teach three specific mathematics concepts. In first and second activities, Meltem asked students questions to have them interpret the geometric rule. She gave some students a chance to make mathematical discoveries by themselves with the teacher computer. However, Meltem could give a few students this opportunity. In the third activity she 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 reaction especially the posing of questions for sense making. In addition, Meltem could check the students' suggestions via GeoGebra. During the

lesson, she tried not to answer her questions; she asked different versions of the same question and gave some examples to have students find the correct answer. As stated above, the only problem in the planning of instruction was time limitation.

#### **4.1.1.3.2 Post Interview III**

After implementing the third lesson, Meltem was interviewed to criticize and reflect on the lesson. The PSTs performance to use educational technology in teaching were criticized by themselves in terms of purpose of the activity (cognitively challenging), the role of the teacher (a guide and help students focus on reasoning), and role of the questions (to led students explore mathematical concepts, discover relationship between mathematical concepts).

In her opinion, the technology usage was very essential in this lesson. She reported on the main issues that have been discussed in the interview were;

in this lesson I implemented three GeoGebra activities. In the second activity students were given problem tasks via GeoGebra and were asked to expand math ideas on the basis of GeoGebra software explorations. First I opened GeoGebra file named transportation system. Then asked students to observe what happens when the pulley is rotated by angle controlled by the slider. Students interpreted the meaning of red curve. (Distance traveled by the red point on the rope). I asked students “How much is the box lifted when the pulley is rotated by  $360^0$ ?”(Circumference of the pulley).Then via educational technology I displayed students the spreadsheet view and they observed the proportionality. I believe this helped them to reach the goal of the lesson.

#### **4.1.1.4 An Overview of Meltem’s Implementations**

Meltem implemented three lessons with the same eighth grade students at a public elementary school in Ankara. Meltem’s teaching showed evidence of change in terms of technology usage levels from the first implementation, to the third based on the TPACK

levels rubric developed by Lyublinskaya and Tournaki (2011). Meltem used GeoGebra software to address mathematics topics by employing GeoGebra as a teaching tool. She combined technology; pedagogy and content knowledge to create technology based teaching activities in a way that led students to a deeper and conceptual understanding of mathematics topics. These three lesson implementations showed that she has the necessary technological, pedagogical and content knowledge to design technology-based activities, and implemented them in elementary school environment.

The constructed GeoGebra activities by Meltem were required advance technical skills to create. In these activities Meltem used dynamic nature of the program. Meltem's first purpose for using GeoGebra in the lessons was simulating a geometrical rule to have students noticed the relationship between geometrical parameters. Activities included dynamic point or slider to move the geometrical objects and demonstrated the change. She put the geometrical concepts together and reorganized them into a new structure through generating and producing based on explorations via GeoGebra. Meltem's second purpose for using GeoGebra in the lessons was modeling a problem task via GeoGebra where students could practice different ways of reasoning and confirm their opinions about the solutions of the problem via measuring lengths, dragging, tracing on, and drawing lines etc. In addition GeoGebra activity also provided hints to assist teacher and students in solution process of a problem. When she had difficulties in getting students to answer the questions, they were attracted by hints and able to answer all questions at the end. The course that she took related to usage of GeoGebra program was ELE 435. Her technological knowledge most likely developed in the content of ELE 430 course. The detailed information about the course was given in Chapter III. Her teaching showed evidence that she has basic pedagogical knowledge to transfer mathematical content via GeoGebra technology to the students. In the lesson plan teaching methods that she used were supported the content and technology. GeoGebra activities included inquiry tasks to implement. In the lesson plan the students presented with question-rich situations that they could explore via GeoGebra under a

variety of conditions and modeling assumptions. Meltem's role was directing students through the solution by ordering sequence of questions at the right time. However, what she planned didn't come true in all lessons. She couldn't communicate students' ideas by making them explore the meaning and relations of the geometrical concepts via GeoGebra especially in the first lesson as she planned. A few students participated into the class discussion and reach the lesson objectives. There was no problematic issue originating from lack of content knowledge in the lessons. Meltem had been pursuing a minor degree in mathematics and this might support the content of her teaching activities.

#### **4.1.1.4.1 Last Interview**

At the end of the three technology-based lesson, PSTs were interviewed about their general opinion about using technology in teaching. In the next sections, detailed information of the participants gathered from last interviews was reported. Before university education Meltem didn't interested in any kind of technology at all. After she took technology-based courses she noticed her ability to using educational technology in teaching effectively. She had no teaching experience in real classroom context previously. The three lessons that she implemented for this study were the first time that she had been a teacher in real classroom to teach mathematics. In Meltem's opinion educational technology is very essential in mathematics education. She emphasizes the importance of the discussion as a teaching method while using educational technology in mathematics teaching. It is not just a tool to make the lesson interesting; it is a teaching tool that gives teachers chance to have students reasoning about the mathematical proofs. During the study she used discussion method in her lesson implementations. She asks questions to have students explore the relationship between mathematical concepts. She reported in the last interview that gaining experience via educational technology in classroom helped her interpret students' behaviors. Meltem also stated the benefits of

implementations, such as becoming aware of her deficiencies in terms of technical knowledge and techno-pedagogical content knowledge and looking for the way to handle these deficiencies. At the end of the study she advised teacher training programs to include technology based courses and implementations to improve PSTs' TPACK level before graduation.

The following section includes excerpts from reflection paper of Meltem. In one of the assignments of ELE 435 course, Meltem reflected on her experiences in this study. One of the questions of that assignment required PSTs to write their opinions about the most educative experience for them. Although this study was not a part of the ELE 435 course, in her Reflection paper, Meltem defined her implementations as most educative experiences for her during that course. Related part of her reflection was;

I had the chance to prepare my own lessons and teach the same class for five (2-2-1) hours. Although it was a volunteer work, not included in the content of this course, I benefited most from this part. Those experiences encouraged me a lot. First of all I had an increasing number of students participating in my lessons through 3 days. Except for the class held in computer lab, classroom management became easier as students get more interested in the class. It showed me how powerful is attracting students' attention for classroom management. Secondly, I always wanted to implement the activities I prepared to real students because I wonder about their reactions and how their learning will be affected. This was the first time I had this chance. Those experiences helped me a lot for trusting 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. Hence, they were the most educative experiences for me.

Meltem's technology-based lessons were a good example for the effective usage of educational technology in math teaching. Meltem's performance in these three lesson implementations represented in the Figure 4.45.

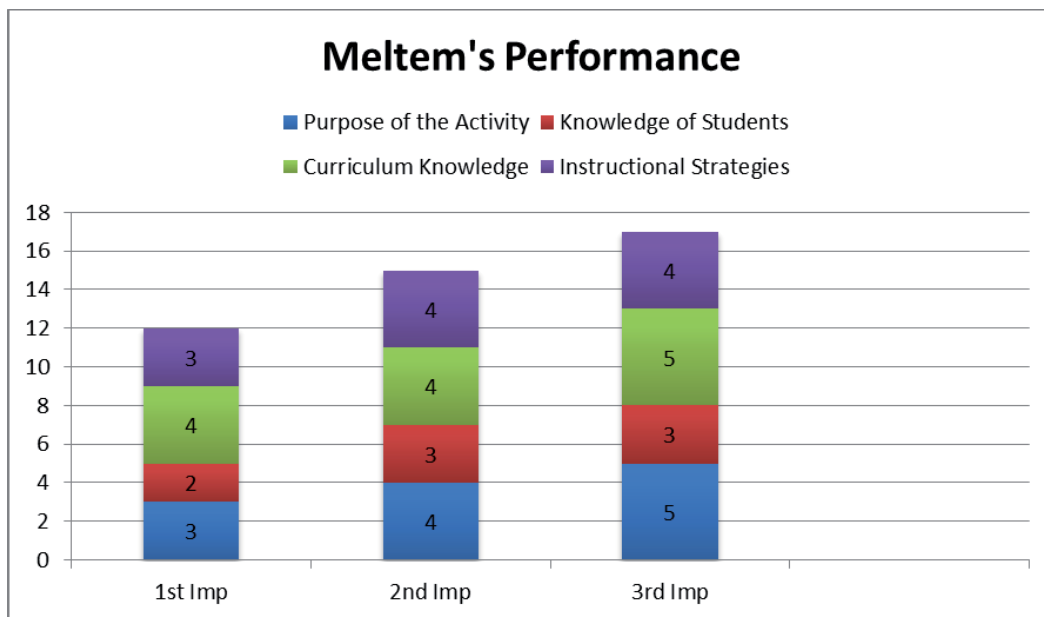


Figure 4.45 Meltem's performance

#### 4.1.2 Case of Pelin

This section presents the findings regarding the case of Pelin. Findings related to the changes and adaptations observed in Pelin in terms of TPACK throughout the implementation of three technology-based lessons during the field experience were explained in the subsequent sections.

##### 4.1.2.1 Findings of Pelin's First Implementation

Pelin implemented her first lesson via spreadsheet program with 28 sixth grade students in the classroom, not in the computer lab. Class included projector and white board, but not computer. Pelin used her personal laptop to project the technology-based activity on the board. The technology-based activity that she prepared for the lesson was her final project for one of the technology course (ELE 429) she took previous semester. She was familiar with the students and classroom environment, since she had already

been in this class for observation in the context of field experience course. The subjects of the lesson were definition of the decimal numbers, digit value of decimal numbers and additions and subtractions with these numbers. Lesson objectives were; the student will be able to define decimal numbers, add two different decimal numbers subtract two different decimal numbers, and solve problems related with decimal numbers. Mentor teacher requested Pelin to teach this subject to be consistent with official curriculum. The teaching method that she planned to use was discussion and problem solving. The aim of the technology-based activity was demonstration of the results in decimal computations. Her goal to use technology in this lesson was to take students attention to the lesson and motivate them to calculate the results. Pelin planned to be guide in the lesson to have students reach the lesson objectives. Pelin felt ready to teach and had no concern about lesson implementation before the lesson. The duration of the lesson was 80 minutes.

At the beginning of the lesson she introduced herself to the students and tell about what mathematics topic she would teach. Then she started lesson with a warm up question. She showed a smiley to the class as presented stated Figure 4.46, and asked students to solve the problem given below.

*Question: “Ayşe divides a paper into 100 square pieces. Then, she draws 11 pieces of it. She said I drew  $\frac{11}{100}$  of it. It is a decimal fraction. Can you define the decimal fraction?”*

A student answered the question.

*Student: Decimal fraction is expressed as a division of two numbers, one number over another. The number in the top is called the numerator, and the number in the bottom is called the denominator. Denominator should be 10, 100, 1000... or it should be available to make 10, 100, 1000, ... by multiplication or division. [v.00:57-01.10].*

*Pelin: Do you agree with your friend? [v.01:12-01.15].*

Students confirmed chorally.

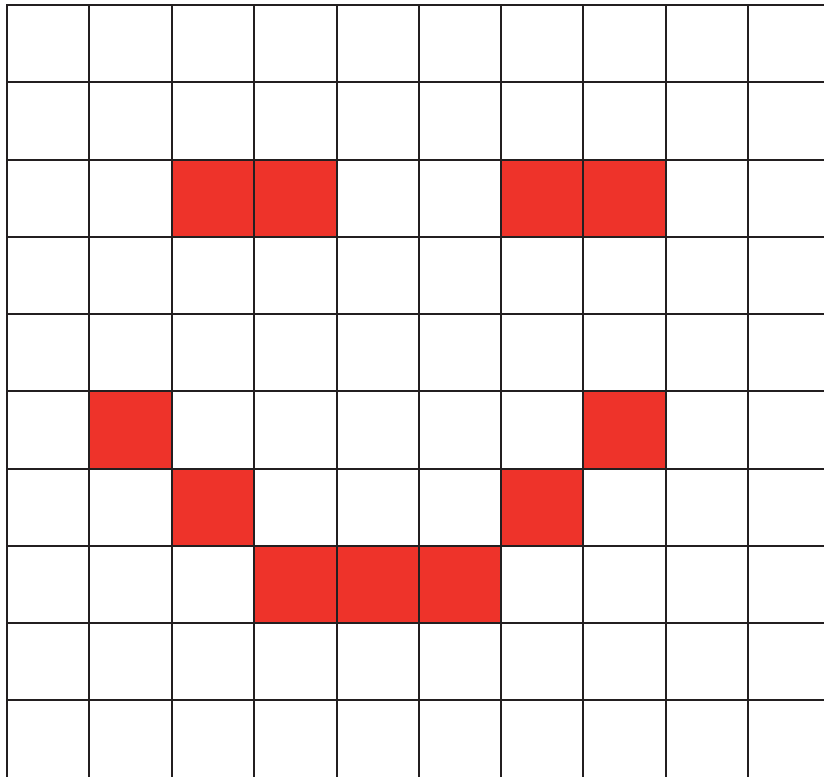


Figure 4.46 A smiley

Then, Pelin asked the difference between decimal fraction and decimal numbers, she wanted them to give examples. She gave students two minutes to think about these concepts. A student answered the question;

*Student: A decimal number has two parts separated by a point. [v.01.25:-01.30]*

*Pelin: Can you give an example?*

*Student: Two point five*

*Pelin: Can you write it on the board? [v.01:42-01.45]*

A student came to the board and wrote 2.5. After that, Pelin explained that a decimal fraction and decimal number are the two different representations of rational numbers.



Up to now, students answered the questions with the help of their pre-knowledge. There were no questions that require students reasoning about definition of decimal numbers. Then, Pelin went on with technology-based activity. She opened the spreadsheet file (see Figure 4.47) and demonstrates the decimal number 4759.26, the words for 4759.26 and digit values of numbers. Pelin showed absolute and fraction parts of decimal numbers by using excel. Then she asked students to give more examples.

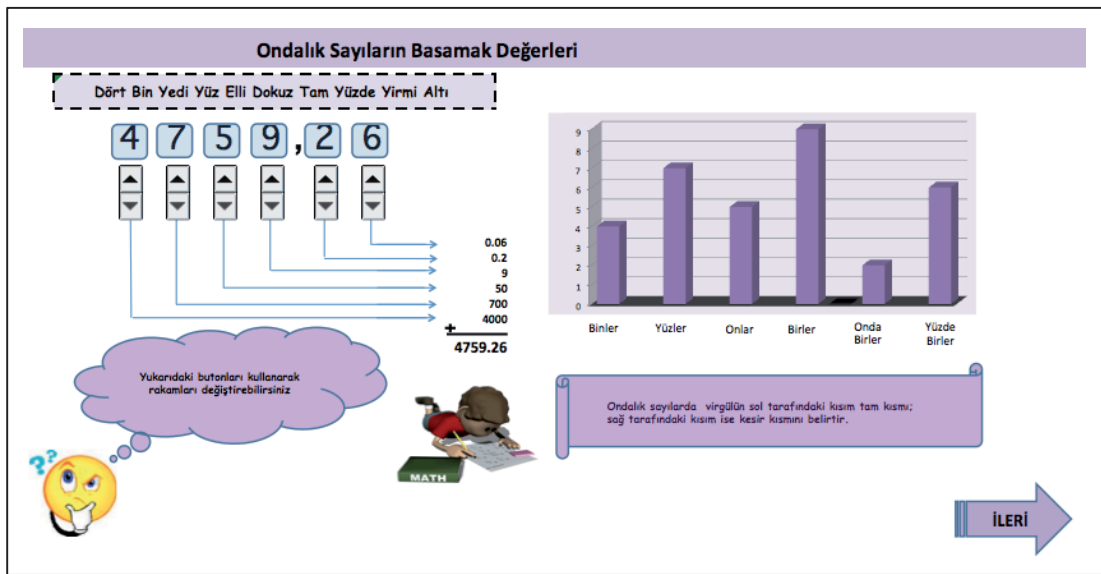


Figure 4.47 Showing digit value of decimal numbers via spreadsheet

Note. English translations of Turkish words are stated below;

Ondalık sayıların basamak değerleri: Digit value of decimal numbers, Dört Bin Yedi Yüz Elli Dokuz Tam Yüzde Yirmi Altı: Four Thousand Seven Hundred Fifty-Nine point Twenty Six

Ondalık sayılarda virgünün sol tarafındaki kısım tam kısım; sağ tarafındaki kısım ise kesir kısmını belirtir: The part of the digits to the left of the point is called the whole number part and the part of the digits to the right of the point is called the fractional part in decimal numbers.

Yukarıdaki butonları kullanarak rakamları değiştirebilirsiniz: You can change the numbers using buttons on tab of the file, İleri: Continue.

Pelin asked students to read the decimal numbers and say digit value of absolute and fraction parts. Since spreadsheet file was dynamic she could change the numbers and give different examples to them. Students could easily see how many thousands, hundred, tens and ones on absolute part and how many tenths and hundredths fraction parts of decimal numbers with the help of graph. Even if the spreadsheet activity requires technical knowledge the way to the usage of educational technology was traditional. Technology-based activity supported to visualization of the decimal numbers.

After that, Pelin opened the operation of addition with decimal numbers page in spreadsheet. She asked students to say two decimal numbers and added them on their notebook. After students found the result, she checked it with the spreadsheet as presented in Figure 4.48.

Toplama İşlemi

Birinci Sayıyı Giriniz

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 2 | 9 | , | 5 | 1 |
| ▲ | ▲ | ▲ |   | ▲ | ▲ |
| ▼ | ▼ | ▼ |   | ▼ | ▼ |

İkinci Sayıyı Giriniz

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 8 | 3 | , | 5 | 8 |
| ▲ | ▲ | ▲ |   | ▲ | ▲ |
| ▼ | ▼ | ▼ |   | ▼ | ▼ |

+

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 2 | 9 | , | 5 | 1 |
| ▲ | ▲ | ▲ |   | ▲ | ▲ |
| ▼ | ▼ | ▼ |   | ▼ | ▼ |

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 8 | 3 | , | 5 | 8 |
| ▲ | ▲ | ▲ |   | ▲ | ▲ |
| ▼ | ▼ | ▼ |   | ▼ | ▼ |

|   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 3 | , | 0 | 9 |
| ▲ | ▲ | ▲ |   | ▲ | ▲ | ▲ |
| ▼ | ▼ | ▼ |   | ▼ | ▼ | ▼ |

Binler Yüzler Onlar Birler Onluk Yüzlük  
Binler Birler

Yandaki butonları kullanarak rakamları değiştirebilirsiniz

Ondalık sayılarda toplama işlemi yapılırken;

- \*Toplanacak kesirlerin virgülleri ve aynı adlı basamakları alt alta gelecek şekilde yazılır.
- \*Toplama işlemine en sağdaki basamaktan başlanır.
- \*Virgül dikkate alınmadan toplama işlemi yapılır.
- \*Toplam, virgüllerin hizasında virgül ile ayrılır.

GERİ

İLERİ

Figure 4.48 Operation of addition with decimal numbers

Then, Pelin explained operation of addition with decimal numbers.

*Pelin: Performing addition operation with decimals is like doing this operation with whole numbers. The difference is the way that you need to write point of decimal numbers on the same line. I mean place values should be lined up the correctly. Then you will perform operation of addition and divide the number into two part absolute and fraction with decimal point [v.07:48-09.00].*

After explanation she asked students to say two decimal numbers. Since spreadsheet file was dynamic she could write the numbers students said and gave the result. Then she asked students different decimal numbers to solve more examples. This time she wrote on the board and asked students to find the results. After that, she checked students' answers with the help of spreadsheet file. Students wanted to perform more questions with spreadsheet. However it caused chaos in the classroom while students saying numbers chorally. Then, Pelin chose students one by one and warned students when they make noise.

After finishing operation of addition Pelin opened the subtraction page as presented in Figure 4.49.

The screenshot shows a digital interface for performing subtraction. At the top, a green checkmark icon is next to the title 'Çıkarma İşlemi'. Below the title, there are two input sections: 'Birinci Sayıyı Giriniz' (Enter the first number) and 'İkinci Sayıyı Giriniz' (Enter the second number). Each section has a grid of buttons for digits 0-9 and a decimal point. The first number entered is 676.69 and the second is 642.85. Below these, the result is displayed as 033.84. To the right of the result, there are buttons for 'Bakiye' (Remainder), 'Yüksek' (Increase), 'Düşük' (Decrease), 'Bölme' (Division), 'Çarpma' (Multiplication), 'Yüzde' (Percentage), 'Bölme' (Division), and 'Yüzde' (Percentage). A thought bubble from a cartoon character says 'Yandaki butonları kullanarak rakamları değiştirebilirsiniz' (You can change the numbers using the buttons on the right). At the bottom, there are 'GERİ' (Back) and 'İLERİ' (Next) buttons. A small cartoon character is also visible in the bottom left corner.

**Çıkarma İşlemi**

Birinci Sayıyı Giriniz: 6 7 6 . 6 9

İkinci Sayıyı Giriniz: 6 4 2 . 8 5

0 3 3 . 8 4

Bakiye Yüksek Düşük Bölme Çarpma Yüzde Bölme Yüzde

Yandaki butonları kullanarak rakamları değiştirebilirsiniz

GERİ İLERİ

Ondalık sayılarda çıkarma işlemi yapılırken:  
\*Eksilen ile çıkan virgülleri ve aynı adlı basamakları alt alta gelecek şekilde yazılır.  
\*Çıkarma işlemine en sağdaki basamaktan başlanır.  
\*Virgöl dikkate alınmadan çıkarma işlemi yapılır.  
\*Bulunan farkın tam ve kesir kısmı, virgüllerin hizasından ayrılır.

Figure 4.49 Operation of subtraction with decimal numbers

Pelin explained how to perform subtraction with decimal numbers by reading the rules she wrote in spreadsheet file and then explained as stated below.

*Pelin: To perform operation of subtraction with decimal numbers we should write numbers first line the numbers up in a column, lining up the decimal points. If the number has not enough digits after the decimal point, we add a zero on the end of so it also has equal digits showing past the decimal point. Then you need start subtraction on the right column, you can ignore the decimal point at the beginning. After you finish regular operation of subtraction you should divide the number into two part absolute and fraction with decimal point in the same line. [v.15:55-16.42]*

Pelin asked students to say two decimal numbers to perform subtraction and a student said a decimal number, another student said the other number. Pelin wrote the numbers 999.348 minus 32.4 on the board and call on student to calculate the answer. After students solved the question, Pelin explained the solution.

*Pelin: The second number has not enough digits after the decimal point, so we add two zero on the end. Subtract down the columns, starting at the right. Notice that in the tenths column  $3 < 4$ . We should borrow from the ones column. [v.19:33-16.42]*

She continued to subtract down the columns, moving from right to left and found 966.948. Students did same procedures with other decimal numbers. Pelin asked students is there anything that they did not understand about the subtraction. Students said no chorally. The purpose of Pelin's activity was drill and practice related to operation of addition and subtraction with decimal numbers. The spreadsheet technology procedures concentrated primarily on compute and visualize the results of the operations. Then, Pelin opened next page in spreadsheet file. At that page, there were five problems related to the addition and subtraction as presented in Figure 4.50.

These problems were prepared for the assessment of the lesson. She asked them to solve in their notebook by themselves. She read the first problem and gave 3 minutes to solve the problem. After that students solved problem and Pelin invited one of the students in front of the class to solve and explain the answer.



**Problemler**



1. Annem, aldığı 8,2 m kumaşın 5,35 m ile kendisine elbise diki. Geriye kaç m kumaş kaldı?
2. Bir manav, iki sandık elma alıyor. Sandıkların birinde 27,5 kg, diğerinde ise 18,750 kg elma vardır. Manav, aldığı elmaların 22,650 kg'ını sattığına göre, kaç kg elması kalmıştır?
3. Evimize perde yapmak için 21 m kumaş aldık. Aldığımız kumaşın 8,5 m'si ile salona, 11,25 m'si ile odalara perde diktirdik. Geriye kaç m kumaş kaldı?
4. Babamın boyu 1,73 m dir. Benim boyum, babamkinden 0,18 m kısıdır. Boyum kaç m dir?
5. Bir otomobil; 312 km'lik yolun birinci saatte 90,53 km'sini, ikinci saatte 89,350 km'sini gitmiştir. Bu otomobilin gideceği kaç km'lik yolu kalmıştır?

2.85

TEBRİKLER :)

23.6

TEBRİKLER :)

5

TEKRAR DENEYİN :(

TEKRAR DENEYİN :(

TEKRAR DENEYİN :(

**GERİ**

Figure 4.50 Problems related to addition and subtraction with decimal numbers.

A student came to the board and solved the problem. After that, he wrote the result on to the box in spreadsheet. This box was prepared by Pelin to make a compliment for students. When students insert the correct answer into the box they saw “congratulations” with smiley, if it was wrong they would saw “try again” with crying smiley as presented in Figure 4.51.

The rest of the problems were solved by students and explained one-by-one. In summary, spreadsheet file provided students a visual environment to check their answers. Students were motivated to compute the results of the computations via technology. At the end of the lesson Pelin asked students whether they had any question about the lesson that they did not understand. Students said no and she finished the lesson.

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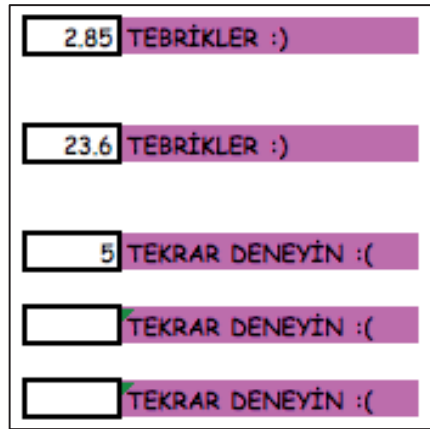


Figure 4.51 Pelin's compliment for students' right answers

#### 4.1.2.1.1 Student Reflection

At the end of the lesson, Pelin asked students to write a reflection paper, in order to evaluate the lesson from students' point of view. The questions for this paper were;

- 1) What have you learned today's lesson? Explain briefly?
- 2) What do you think about the use of technological tool while learning this geometric issue? Explain your reasons.
- 3) In which part of the lesson you enjoyed?
- 4) In which part of the lesson you bored?
- 5) How do you evaluate your performance in class discussion? What was the most difficult part for you? If you give yourself a score out of 10 what would be this score?
- 6) Is there anything that you want to add related to this lesson?

During the last five minutes of the class time, students were asked to write their reflections to the lesson to provide feedback about the lesson implementation to Pelin. For doing this, Pelin projected the set of reflective questions stated above on to the

board. Thirty out of 33 students comment about the lesson were favorable. Students were pleased to have been taught this topic via spreadsheet. For example, 7 of the students reported that spreadsheet was so practical in terms of visualization. One of the students comments was “it was an opportunity seeing the result of operation visually on the board was so entertaining that it motivated them to calculate. One of the students comments was “This lesson was different than I am used to. I liked the smiley. It took my attention.” On the other hand, 3 of the students reported that technology usage was not crucial for this lesson to learn operations of decimal numbers.

In this lesson, technology was used for motivate students to the calculation of decimal operations. It is appeared to motivated students to solve the drill and practices and when they saw the “congratulations” with smiley. However, apart from this, Pelin’s usage of educational technology was not very effective.

#### **4.1.2.1.2 Pelin’s First Lesson Performance**

In the first lesson, Pelin’s performance for the C1 was consistent with the recognizing level. C1 mainly related to the purposes of integrating technology in teaching mathematics. The purpose of using educational technology in teaching was drill and practice. Recognizing level is the first level to use educational technology in teaching. In recognizing level, educational technology used *only for practice, and all learning of new ideas done through the teacher mostly without technology*. In this lesson educational technology was used to generate addends and subtrahends in the standard algorithms. In addition in this lesson, when students insert the correct answer into the box in spreadsheet, students they saw “congratulations” with smiley, if it was wrong they would saw “try again” with crying smiley. It can be said that educational technology used to motivate students to calculate the results of operational computations procedurally. Without this technology, it was also available to have students practice in

decimal numbers. This lesson was not an example for the effective usage of educational technology.

Pelin's performance for the C2 was consistent with the recognizing level. C2 mainly related to the PSTs' knowledge of students' understandings, thinking, and learning in technology-based mathematics lesson. In this lesson, technology-based activity didn't support students' conceptual understanding. In recognizing level, *technology is used primarily for student practice. A document does not present any new material, and only provides space for applications and drills.* Students did not use technology to explore math ideas. The nature of the technology-based activity wasn't planned to explicitly promote student knowledge by posing of questions for sense making. Therefore, there was no question, which requires students reasoning about definition of decimal numbers. Pelin asked students drill and practice about operations of decimals. Nevertheless, students enjoyed the visual supports of technology and motivated to calculate decimal operations.

Pelin's performance for the C3 was consistent with the recognizing level. C3 mainly related to the PSTs' knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics. In this lesson, lesson objective were; students should be able to define decimal numbers; add two decimal numbers and subtract two different decimal numbers. The lesson was not well structured and spreadsheet task wasn't built around learning objective. In recognizing level, *teacher does not use technology for learning mathematics.* Smiley warm-up question indicated that Pelin has prerequisite content knowledge to have students explore decimal computations via area or grid model; however; she didn't create a technology-based activity, which includes these models. This might be because of the she has limited technical knowledge to create these models via technology. In this lesson, Pelin didn't use technology to teach a specific mathematics concept, she used technology for drill and practice only. She didn't ask any challenging question to students in order to have them think about the mathematical concept.



Pelin's performance for the C4 was consistent with the recognizing level. C4 mainly related to the knowledge of instructional strategies and representations for teaching and learning mathematics via technology. This lesson was a teacher-directed lesson. In recognizing level, *teacher focuses on how to use technology rather than how to explore math ideas, using teacher-directed lectures followed by student practice. Technological activity document provides students only with opportunities for drill and practice.* In this lesson, Pelin's role was lecturer. Using teacher-directed lectures followed by students practice. During a large part of class time, Pelin used a spreadsheet to demonstrate standard algorithms. The way to teach this topic via technology was teacher centered.

#### **4.1.2.1.3 Post Interview I**

After implementing the first lesson, Pelin was interviewed to criticize and reflect on the lesson. The PSTs performance to use educational technology in teaching were criticized by themselves in terms of purpose of the activity (cognitively challenging), the role of the teacher (a guide and help students focus on reasoning), and role of the questions (to led students explore mathematical concepts, discover relationship between mathematical concepts).

In her opinion, the technology usage was not essential in this lesson; without this technology it was also possible to display the information on the board. The advantage of technology was motivating students to the lesson and preventing time consuming since they didn't need to have extra verification for the results of the operations. She stated that educational technology needed to be integrated into mathematics to ask students challenging questions in a way that support students' conceptual understanding. She reported on the main issues that have been discussed in the interview were;

I think, students liked my spreadsheet file, they engage into the lesson, answer the questions. Smileys motivated them to solve the drill and practices. However,

the technological activity didn't support their conceptual learning. I didn't ask challenging questions by using educational technology. I used technology in a traditional way to demonstrate operations. Next time while integrating technology into mathematics, my first priority will be ask students challenging questions to support their conceptual understanding via technology.

For the next implementation, she would consider drawbacks of this lesson and plan to design more professional a technology based lesson implementation.

#### **4.1.2.2 Findings of Pelin's Second Implementation**

Pelin implemented her second lesson via GeoGebra program with 30 eighth grade students in the computer lab. Computer lab includes 15 computers, a teacher laptop, projector and white board. Every one or two students could have one computer during the lesson. Pelin used the teacher laptop to project her GeoGebra file onto the board. The technology-based activity that she prepared for the lesson was one of the final projects prepared for ELE 429 course by one of the other PSTs. She wasn't familiar with the students, since she had never been in that class for observation previously. The subjects of the lesson were inequalities of triangles, angle-side properties. Lesson objectives were; the student will be able to put in order the sides of a triangle based on their angles; put in order the angles of a triangle by looking at their sides; decide if they can draw a triangle by looking at three lengths. Mentor teacher requested Pelin to teach this subject to be consistent with official curriculum. The teaching method that she planned to use was discussion and problem solving. The aim of the technology-based activity was discovering triangle inequality and angle-side relationship in a triangle via GeoGebra. Pelin planned to be a guide in the lesson to have students reach the lesson objectives. Pelin felt ready to teach and had no concern about lesson implementation before the lesson. The duration of the lesson was 80 minutes.

At the beginning of the lesson she introduced herself to the students and tell about what mathematics topic she would teach. This topic was new for students. She asked

students if they and their computers were ready to start the lesson. After students confirming, she asked students to open the GeoGebra program. Students were familiar with the dynamic geometry program since, one of the participants of this study implemented a technology-based lesson with this class previously. However, this lesson was the first experience for students to study with GeoGebra program in lab environment by themselves.

First of all, she introduced GeoGebra menu and had students construct a line segment with given lengths. Then she displayed how to drag this line segment from one place to another via mouse. She gave two minutes wait time to be sure that students constructed the line segment and moved it in the GeoGebra file. After that, she gave students three lengths to use to construct a triangle. The lengths were; 3, 7, 11. Pelin gave directions; come to the third component of the menu, choose the “segment with given length from point” and construct three lines for 3, 7, and 11. She constructed the line segments with teacher laptop as presented in Figure 4.52.

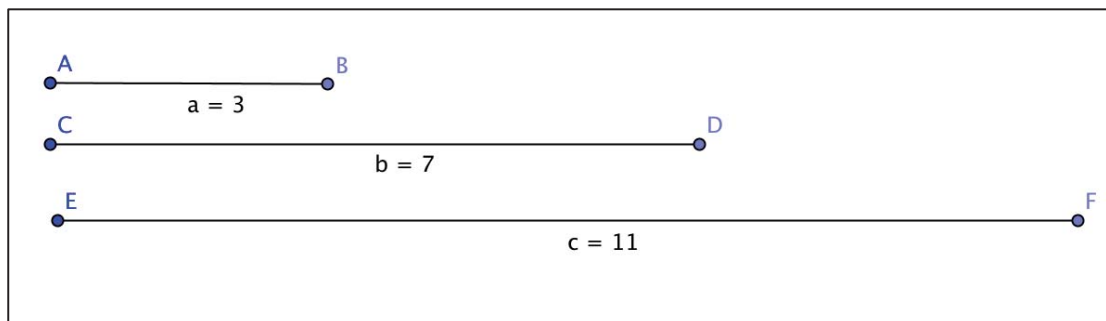


Figure 4.52 The lengths of the line segments to construct a triangle

Then, she asked students to move the lines to make a triangle. Students move the lines but they couldn't construct a triangle (as presented in Figure 4.53). Students said in choral response;

*Students: 11 is too long to construct a close shape.*

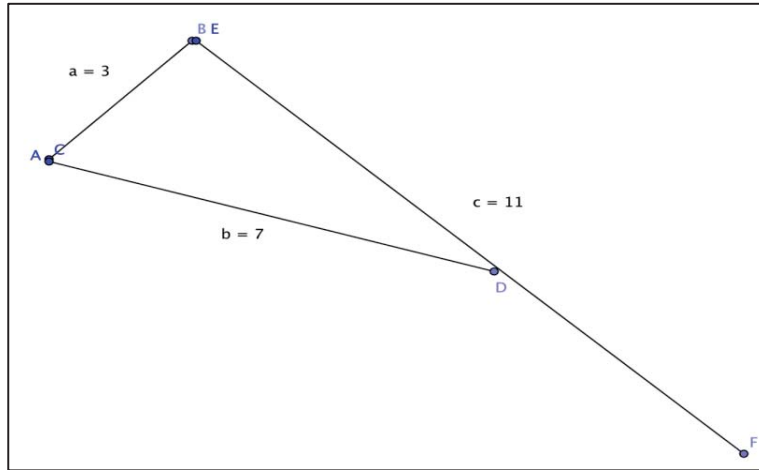


Figure 4.53 It is not possible to construct a triangle with given lengths

In the lesson Pelin's role was guide. Therefore Pelin didn't make any comment, instead, she asked students to try to make another triangle with 5, 5 and 11. Students move the lines once again but they couldn't construct a triangle. Students said that;

*Student: Eleven is too long.*

Then she asked students to draw a triangle with sets of segments 3,7,10 - 5, 4,11 - 2, 3,6 and 3,5,9 respectively. Students couldn't construct any triangle with these groups of numbers. During the lesson Pelin was walking around the classroom and checking students' work on their monitors. After six unsuccessful initiatives, she asked students to draw a triangle with 3, 4, and 5.

She gave a minute wait time to students.

*Pelin: Is there anyone who could construct the triangle?*

*Students: Yes, [v.16:35-16:40] in choral response.*

There were students, who were able to construct the triangle as presented in Figure 4.54. Students asked Pelin to see their triangle. She checked each student's work in his or her GeoGebra file.

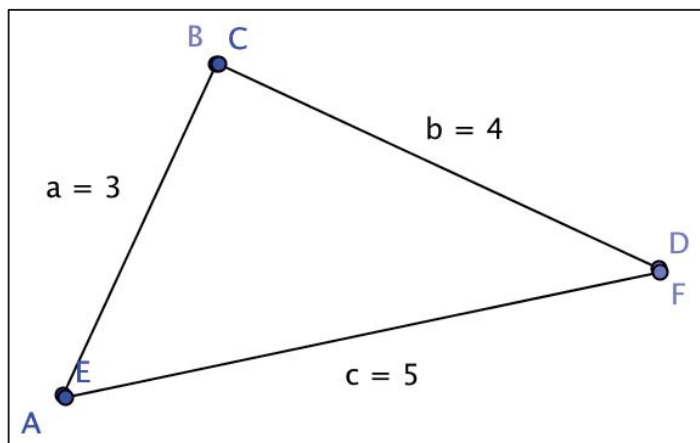


Figure 4.54 Students constructed a triangle

Students drew one more triangle for the 6,7 and 11. Pelin continued the lesson on the board by displaying each group of lengths that she gave students to draw a triangle. She asked the students;

*Pelin: Why you couldn't draw a triangle with the numbers at the beginning. What was wrong with that group of numbers? How could you draw a triangle with the other group of numbers? What is the difference between them? Is there anyone who wants to share her/his ideas?*

*Student: Some of the numbers were not long enough to close the shape.*

*Students: And some of them were too long to close the shape.*

*Pelin: What do you mean?*

*Student: I think three of the lengths should be close each other, not too long and not too short.*

*Pelin: Do you mean, is there a relationship between lengths of the triangle sides?*

*Student: Yes, kind of but, I couldn't explain it exactly.*

*Pelin: Let's look at the numbers again and try to see the relationship.*

*The lengths were 3,7,11 – 5,5,11 – 3,7,10 – 5,4,11 – 2,3,6 and 3,5,9 that we couldn't construct a triangle, and 3, 4, 5 and 6, 7, 11 were the lengths that we construct a triangle. Could you see a relationship between these numbers?*

*Student: While we couldn't construct a triangle with 5, 5, 11, we could with 6,6,11. The different numbers are 5 and 6.*

*Pelin: He is right, isn't he?*

*Student: Yes he is right?*

*Pelin: So, what is the relationship? Let's propose a relationship and check it out for all groups of the numbers*

*Student: If we add two sides' lengths of the triangle the sum should bigger than the other side.*

*Pelin: Let's check it out.  $5+5=10$  and it is smaller than 11 so we couldn't draw the triangle. Is there anyone who wants to more any other example about this?*

Pelin gave 2 more examples to verify the rule. Then one of the students said that;

*Student: The length of a triangle's side should be, smaller than the sum of the other two sides and bigger than difference of the other two sides. What I mean is it should be between sum and difference. [v.19:13-19:20]*

*Pelin: You mean in addition to the previous rule, the difference between two sides should be shorter than the other side, didn't you. Let's check this out with examples.*

Students gave examples about this rule and they appeared to agree that this rule is true.

In this part of the lesson, Pelin used pedagogical knowledge to be a guide for students to discover geometrical rules. Students constructed triangles and explored the relationship between lengths of side.

Pelin visualized the triangle inequalities via GeoGebra program. By dragging the dynamic vertex points of the triangle, she displayed that the rule is always true.

Pelin wrote the general formula of the inequality on the board.

$$|a - b| < c < a + b$$

$$|a - c| < b < a + c$$

$$|b - c| < a < b + c$$

After that, Pelin continued to the second part of the lesson. She asked students to draw a triangle via GeoGebra. Pelin displayed them how to construct a triangle via GeoGebra by projecting on to the board. Then, she asked them to find the measures of the angles and lengths of the sides as presented in the Figure 4.55.

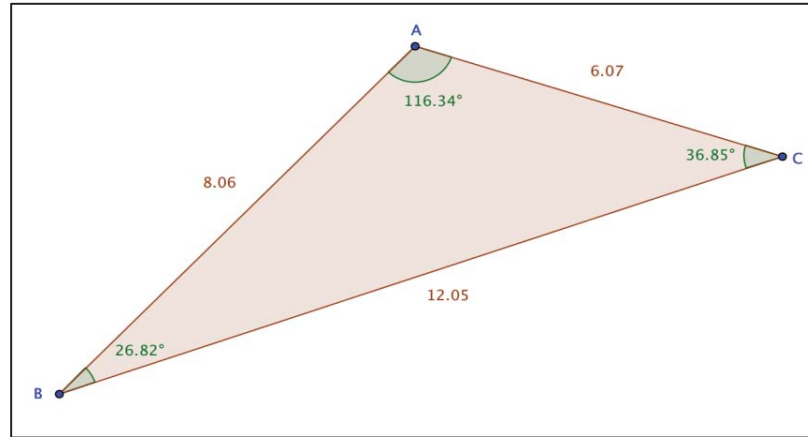


Figure 4.55 Angles and lengths of the triangle were highlighted

After that, Pelin asked students to drag one the dynamic vertex points of the triangle and observe. She asked students to make an interpretation about the relationship between the length of the sides and angles of the triangle. She asked;

*Pelin: Which side of the triangle is the longest? [v.25.23:-25:28]*

Three of the students said the length of the long side in their triangle. Then, she asked them to check the angle that the longest side is opposite from to see if it was the biggest one. Students agreed that it was. Then they talked about the other triangles that they constructed by dragging a vertex and discussed the relationship between their sides and angles. They discussed and made a statement; the biggest angle in the triangle has the longest side, so, there is long side across the big angle and there is short side across the small angle. They checked the statement that they discovered via GeoGebra for five minutes. After finishing the first lesson, Pelin gave a 10 minutes break. In the second lesson, Pelin have students solve the additional drill and practices related to triangle inequalities. At the end of the lesson Pelin asked students if they have any question about the triangle inequalities. Students said no and she finished the second lesson.

From the beginning of the lesson to the end, technology activities included inquiry tasks. To develop connections between geometrical concepts, Pelin engaged students into the lesson by asking questions about the triangle inequalities. Students made experiment via GeoGebra program and answered the questions. Then they created a conjecture about the relationship between the side and the sum of the remaining sides in a triangle, and also the angles and their opposite sides in the triangle.

#### **4.1.2.2.1 Student Reflection**

At the end of the lesson, Pelin asked students to write a reflection paper, in order to evaluate the lesson from students' point of view. The questions for this paper were the same as in previous lesson with an additional question. This question was added to have students' preferences being in the computer lab and classroom while working GeoGebra program. The question was;

- Do you prefer being in the classroom instead of being in the computer lab while working with GeoGebra program?

During the last five minutes of the class time, she projected a set of reflective questions on the board. Students were asked to write their reflections to the lesson implementation. Twenty-seven out of 30 student comments about the lesson were favorable. According to their answers, students were pleased to learn triangle inequalities via GeoGebra program in lab environment. Twenty-three of the students appreciated being in the computer lab in this lesson. For example, one of the student comment was "I prefer being in the lab environment since I had a chance to try to construct the triangles by myself and observe if the lengths are applicable to construct a triangle. I think I understand better by doing this experiment." Seventeen of the students reported that learning with GeoGebra provide advantages in terms of easy drawing, effectiveness, visualization, clearness and joyfulness. One of the student comments



related to advantages of the GeoGebra. For example, “via GeoGebra I could draw the three segments easily and see why I can or cannot construct the triangle. In addition, it was so much fun, I enjoyed.” Eight of the students reported that “with the help of GeoGebra, I could observe the relationship between the lengths of sides in a triangle.” Not all of the comments were positive. One of the students comments was “in mathematics lesson; I need to draw myself to understand what is happening, I believe. I prefer drawing with paper and pencil.” Seven of the students didn’t like to be in lab environment. Five of the students reported that just because they feel more comfortable in classroom environment they don’t prefer being in the computer lab for the lesson. The other two suffered from sharing their computer in the lab. One of the student comment was, “I couldn’t concentrate on the lesson since I was sharing my computer with my friend. It was not comfortable; I wait so much time to have my turn.”

In this lesson, students made explorations via GeoGebra program to discover the triangle inequality and angle-side relationship. Students reported that educational technology was very helpful for them to discover relationships between geometrical concepts.

#### **4.1.2.2.2 Pelin’s Second Lesson Performance**

In this lesson, Pelin’s performance for the C1 was consistent with the adapting level. Pelin’s level for the C1 increased from recognizing level to adapting level. C1 mainly related to the purposes of integrating technology in teaching mathematics. The purpose of using educational technology in the second lesson was to have students experience with mathematical explorations via GeoGebra program. In adapting level; *teacher use technology in a way that is new and different from teaching without this technology (dynamic nature, linked representations) and used for learning new knowledge by students*). In this lesson Pelin used dynamic nature of the educational technology to provide an environment to support students’ learning new mathematics

knowledge by doing explorations via educational technology. The aim of the technology-based activity was discovering triangle inequality and angle-side relationship in a triangle via GeoGebra program. For this aim, Pelin suggested two activities to the students. In the first activity, students formed a triangle with given side lengths. The GeoGebra technology procedures concentrated primarily on constructing three lines and exploring if the three segments form a triangle. In the second activity students dragged the vertices of triangle and using measurement tool, they examined angle-side relationship. Students had a chance to see if the longest side has the largest angle, or shortest side has the smallest angle. Without this technology it was also possible to implement this activity via physical manipulatives. For example, with the help of pasta, students could cut the pieces a given lengths and try to construct a triangle. Then, they could also measure sides and angles of various triangles and investigate the triangle inequality and angle-side relationship in a triangle. Nevertheless, the usage of GeoGebra program is practical than pasta while constructing triangles and there might be some measuring errors as well.

Pelin's performance for the C2 was consistent with the adapting level. Pelin's level for the C2 increased from accepting level to adapting level. C2 mainly related to the PSTs' knowledge of students' understandings, thinking, and learning in technology-based mathematics lesson. In adapting level, *teacher focuses on students' thinking of mathematics while students are using technology on their own – both for learning new knowledge and review of prior knowledge*. This lesson implemented in computer lab and students worked with GeoGebra program for their own learning of new geometrical concepts. Students explored mathematical relationship and confirmed their reasoning about this relationship in order to discover triangle inequality and angle-side relationship in a larger part of the class time with educational technology. Via educational technology, students tried to create a triangle with given lengths and observed in which condition these three lengths construct a triangle. To reach the general overview, students shared their ideas about the relationship between these geometrical concepts

and tested their conjectures via GeoGebra. Then students made general conjecture about triangle inequalities and reached the rules. Students followed the same procedure to discover the angle-side relationship in a triangle. In the lesson she focused on students' thinking of mathematics by asking questions. Students enjoyed the technology and motivated to discover the geometrical rules by themselves.

Pelin's performance for the C3 was consistent with the accepting level. Pelin's level for the C3 increased from recognizing level to accepting level. C3 mainly related to the PSTs' knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics. In accepting level, *teacher uses standard approach to the curriculum topics with technology being used as add-on. Technology is partially aligned with one or more curriculum goals.* In the second lesson Pelin considered drawbacks in the first lesson and she used technology not only for drill and practice but also teaching a specific mathematics concept. The lesson objectives of the lesson were; students should be able to put in order the sides of a triangle based on their angles; students should be able to put in order the angles of a triangle based on their sides; students should be able to decide if the sides lengths are available to construct a triangle or not. For this lesson Pelin didn't construct a special GeoGebra task, she used standard menu of it to have students noticed triangle inequality and angle-side relationship. Nevertheless, she could construct an activity to visualize these relationships as they constructed in ELE 430 course. In the activity constructed in ELE 430 course there were dynamic checks boxes for two different texts related to triangle inequalities. In the first text box it can be seen that the sum of two sides' of triangle is longer than the other side for three possible situations. By dragging the dynamic vertex points of the triangle, it could be displayed that this rule is always true. The inequalities in the check boxes recalculated themselves. The GeoGebra file constructed in the course was presented in Figure 4.56.

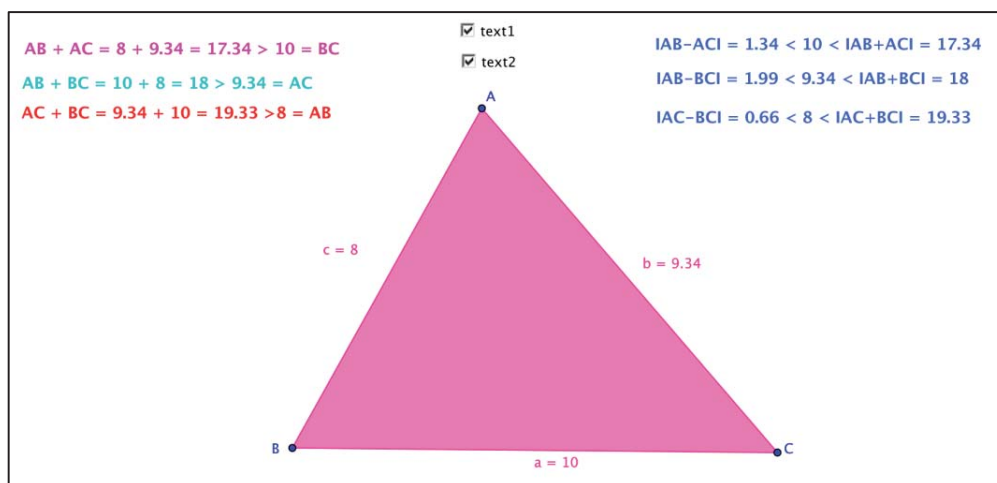


Figure 4.56 The GeoGebra activity constructed in ELE 430 Course

Pelin's performance for the C4 was consistent with the adapting level. Pelin's level for the C4 increased from recognizing level to adapting level. C4 mainly related to the knowledge of instructional strategies and representations for teaching and learning mathematics via technology. In the lesson, Pelin used technology as a tool to help students' discover relationships between geometrical concepts in the computer lab. In adapting level, *teacher uses, teacher- directed approach with more focus on mathematics discoveries with technology*. In the lesson Pelin's continuously asked students to do something via educational technology. Nevertheless, since, educational technology provided an environment for students to do mathematics with discoveries, Pelin served as a guide of student learning with technology time to time. Pelin asked students questions to enhance their investigations. Her goal was to have students make a judgment related to the triangle inequality and angle-side relationship through checking and critiquing. Pelin enhanced the discussion when she asked students to make comparisons between sets of side measures that made a triangle and sets of sides that did not work. However, she didn't ask any what- if question such as *what if, a triangle has*

*the sum of the measures of the two sides equal to the measure of the third side to challenge them.*

#### **4.1.2.2.3 Post Interview II**

After implementing the second lesson, Pelin was interviewed to criticize and reflect on the lesson. The PSTs performance to use educational technology in teaching were criticized by themselves in terms of purpose of the activity (cognitively challenging), the role of the teacher (a guide and help students focus on reasoning), and role of the questions (to led students explore mathematical concepts, discover relationship between mathematical concepts).

In her opinion, this time usage of educational technology was essential in this lesson. Without this technology it is also possible to have student reach the lesson objectives via physical manipulatives. However, having students make experiment to discover triangle inequality and angle-side relationship via physical manipulatives would be difficult and time consuming. The advantage of technology was usability and saving time. Via GeoGebra program, students could construct triangles with given size and explore the relationship between its elements. Technology prevented time consuming since students measure neither side nor angle of the triangle. The measures of the elements were dynamically included in the GeoGebra program. She stated that educational technology assisted her to ask questions to the students and helped them discover relationships between mathematical concepts. She reported on the main issues that have been discussed in the interview were;

during the lesson, students made experiment via technology and tested their conjectures about the triangle inequality and angle-side relationship. I asked questions to force them think about the conjectures. They discussed their opinions. I used educational technology as a tool to ask questions and they use technology to test and explain their conjectures. I believe that in this time educational technology was used more efficient way when I compare the first lesson. Next time I hope I will plan more effective lesson via GeoGebra”

Pelin considered the drawbacks of previous lessons and aimed to implement more professional lesson in the second one.

#### 4.1.2.3 Findings of Pelin's Third Implementation

Pelin implemented her third lesson via GeoGebra program with 31 eighth grade students in the classroom, not in the computer lab. Class included projector and white board, but not computer. Pelin used her personal laptop to project the technology-based activity on the board. The technology-based activity that she used in the lesson, was prepared by another PSTs as a final project for ELE 430 course. She wasn't familiar with the students and classroom environment, since she had never been in that class for observation previously. The subject of the lesson was algebraic identities. Lesson objective was; the student will be able to represent identities with geometrical models. Mentor teacher requested Pelin to teach this subject to be consistent with official curriculum. Pelin taught  $(a+b)^2 = a^2 + 2ab + b^2$ ,  $(a-b)^2 = a^2 - 2ab + b^2$ ,  $a^2 - b^2 = (a-b)(a+b)$  identities. Mathematics teacher stated that students have prior knowledge about basic components of identities to learn this topic. Students did not have any information about the GeoGebra program. *The teaching methods that she planned to use were discussion and direct teaching.* The aim of the technology-based activity was representing dynamic models for the identities. Her goal to use technology was to explain the construction of these geometrical models to the students. Pelin planned to be guide in the lesson to have students reach the lesson objectives. Pelin felt ready to teach and had no concern about lesson implementation before the lesson. The duration of the lesson was 80 minutes.

In this lesson Pelin used two GeoGebra activities. The first GeoGebra activity was the geometrical model of the  $(a-b)^2 = a^2 - 2ab + b^2$  identity. In this file there were two squares one was inside the other. Squares side lengths were connected with the sliders, so it was available to change the side lengths dynamically. In addition there were two checks box one for dynamic formula and one for the text on the squares to show the

name of the sides. Via this GeoGebra file students could see the geometrical model of  $(a-b)^2 = a^2 - 2ab + b^2$  identity visually. With the help of sliders, students could change the side length of the squares and observe that no matter the numbers changes, the identity never changes. In the second file there was a geometrical model of  $a^2 - b^2 = (a-b)(a+b)$  identity. In the model, there was a big square and a small square, two trapezoids in it. The big square was the  $a^2$  and a small square was the  $b^2$ , two trapezoids were the difference between them. Each part of the model was different color. In the file there were five sliders and three check boxes as well. First and second sliders were to change the side lengths dynamically. Third and fourth sliders were to subtract trapezoids out from the big square. The last slider was constructed step by step to show the process of how to make a rectangular with two right trapezoids. The movements of the trapezoids were connected with the slider by using “condition to show objects” property of GeoGebra.

At the beginning of the lesson she introduced herself to the students and tell about what mathematics topic she would teach. Then, she starts the lesson with a question;

*Pelin: Can you explain what identity is? [v.00.35-00.40].*

*Student: Equity of two expressions.*

*Student: A relationship between two numbers that all of the numbers has that relationship.*

*Pelin: What is the difference between equation and identity?*

*Student: The equation is true for the roots of that equation, but as we said before all of the numbers has that relationship in identity.*

*Pelin: You are right. In this lesson we are going to learn geometrical representation of some algebraic identities. Let's start with the first identity. I want you to have an A4 paper. Can you fold it to make a square as I showed you?*

Pelin started the lesson with hands-on activity. She folded the one corner of the A4 paper until it meets the opposite edge, forming a triangle. Then she tore the extra paper from the bottom. Finally she made a square. Students constructed a square as well. She asked students to mark a point on any sides like A on their paper and fold. Then, she asked students to fold the one corner of the paper, forming a triangle as presented in

Figure 4.57 After that Pelin marked the other vertex of the triangle as B. Then Pelin drew a figure on a board with chalk to explain what she asked.

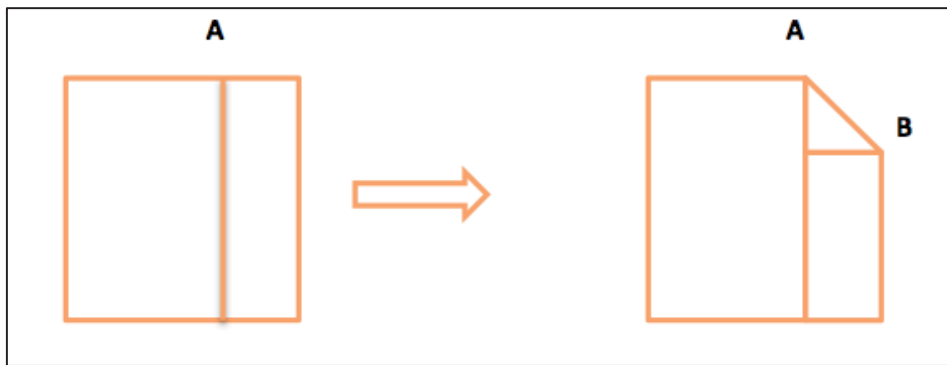


Figure 4.57 Students folded the square paper

She asked students to draw a line along the folded parts as presented in Figure 4.58.

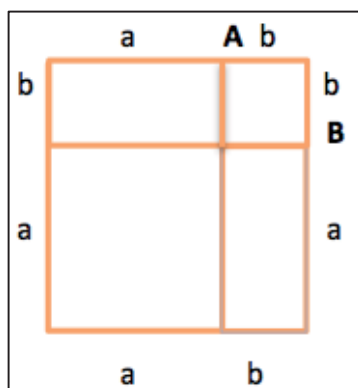


Figure 4.58 Students drew lines along the folded parts

She asked;

*Pelin: How many squares are there in this figure?*

*Student: Two.*

*Pelin: How many rectangular are there in this figure?*

*Student: Two*



*Pelin: Can you identify the side of the squares?*

*Student: Yes there is a small square its side is “b” and big square its side is “a”*

*Pelin: What about rectangles?*

*Student: There are two identical rectangles in it and their sides are “a” and “b”*

*Pelin: Then we have one big square whose side is “a+b”. We divide it into two squares and two rectangular.*

*Pelin: What can you say about the areas of the geometrical shapes?*

Then, Pelin asked students to write with letters the area of the big square and sum of the areas of the geometrical shapes in the big square. After that, she gave students five minutes to write. Finally student wrote the areas of the geometrical shapes.

*Pelin: Can you make a comparison between the area of big square and sum of the geometrical shapes in it? Are the areas same or different?*

*Student: Areas are the same and my equation is  $(a+b)^2 = a^2 + 2ab + b^2$ .*

*Pelin: Yes you are right. Can you write the similar equation for  $(a+2b) = ?$*

Pelin gave students three minutes to write. Students wrote and she checked the answers. Pelin continued the lesson with  $(a-b)^2$  identity. She asked students to try to make geometrical modeling of this identity as they did  $(a+b)^2$  identity. Then she gave two minutes wait time to the students. She paired the students to model the  $(a-b)^2$  identity. Two minutes later she asked students.

*Pelin: Who wants to share their idea about the modeling  $(a-b)^2$  identity?*

*Student: We need to draw a big square.*

*Pelin: Why square?*

*Student: Because we did same thing with  $(a+b)^2$*

*Pelin: Why we choose a square?*

*Student: We are looking for a square, square of  $(a-b)$ . This might be the reason.*

*Pelin: Right, this is why we started with the square. Now I want to see your drawing on the board. Is there any volunteer?*

One of the students came to the board and drew her modeling as presented in Figure 4.59.

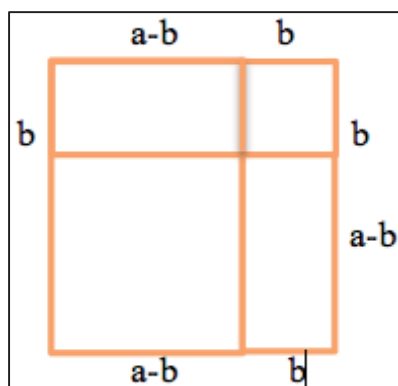


Figure 4.59 Student's model of  $(a-b)^2$  identity

*Pelin: Can you explain your modeling?*

*Student: The One side of the big square is "a". I subtracted "b" from "a" and as you see there was constructed a square whose side is (a-b). To find the " $(a-b)^2$ " I should subtract two rectangular and small square from big square to have the  $(a-b)^2$ . If I wrote what I say mathematically*

*If I wrote simpler way*  $a^2 - [2 \cdot (b(a-b) + b^2)] = (a-b)^2$

$$a^2 - [2ab - 2b^2 + b^2] = (a-b)^2$$

$$a^2 - 2ab + b^2 = (a-b)^2$$

Pelin confirmed the student answer and asked if there is any other modeling for  $(a-b)^2$  identity. There was no other solution. Pelin said;

*Pelin: I have another model for this identity. I construct it via GeoGebra program. We will continue next lesson with that file. [v.23.42-23.48].*

The bell has been rang and students had a break. At the beginning of the next lesson Pelin opened the GeoGebra file and projected it on the board as presented in Figure 4.60

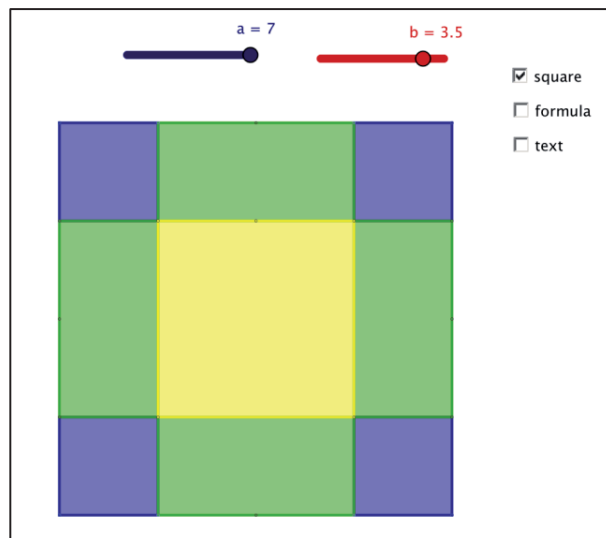


Figure 4.60 Pelin's model of  $(a-b)^2$  identity

Pelin displayed Figure 4.60 in GeoGebra file without text and formula to ask question about the model. Pelin asked her first question to the students;

*Pelin: What might be the length of a side of the big square?*

*Student: It might be "a"*

*Pelin: Right. What about "b"*

*Student: One side of the small square might be "b"*

*Pelin: Himm, then it seems we subtract two "b" from "a"*

*Student: No, we want to subtract "b" from "a"*

*Pelin: Then one side of the small square might be?*

*Student: It is  $b/2$ .*

*Pelin: That is true. What about the rectangles?*

*Student: Its one side is " $\frac{b}{2}$ " and the other side is " $a - \frac{b}{2} - \frac{b}{2}$ " well it means " $a-b$ "*

*Pelin: Then the area of the middle square is?*

*Student:  $(a-b)^2$  [v.01.14-01.17].*

*Pelin: Now we want to find what  $(a-b)^2$ . Do you have any idea how can we get this identity from this model?*

*Student: To get the  $(a-b)^2$  we need to subtract the four rectangular and four small squares from the big square.*

Then Pelin gave two minutes to write the subtraction with letters. After that one of the students came to the board and wrote the solution as stated below.

$$\begin{aligned} \text{Therefore it is } a^2 - \left\{ 4 \left[ \left( \frac{b}{2} \right) \cdot (a-b) + \left( \frac{b}{2} \right)^2 \right] \right\} &= (a-b)^2 \\ a^2 - \{ 2[b(a-b) + b^2] \} &= (a-b)^2 \\ a^2 - [2ab - 2b^2 + b^2] &= (a-b)^2 \\ a^2 - 2ab + b^2 &= (a-b)^2 \end{aligned}$$

Afterwards, Pelin ticked the formula and text check boxes as stated Figure 4.61.

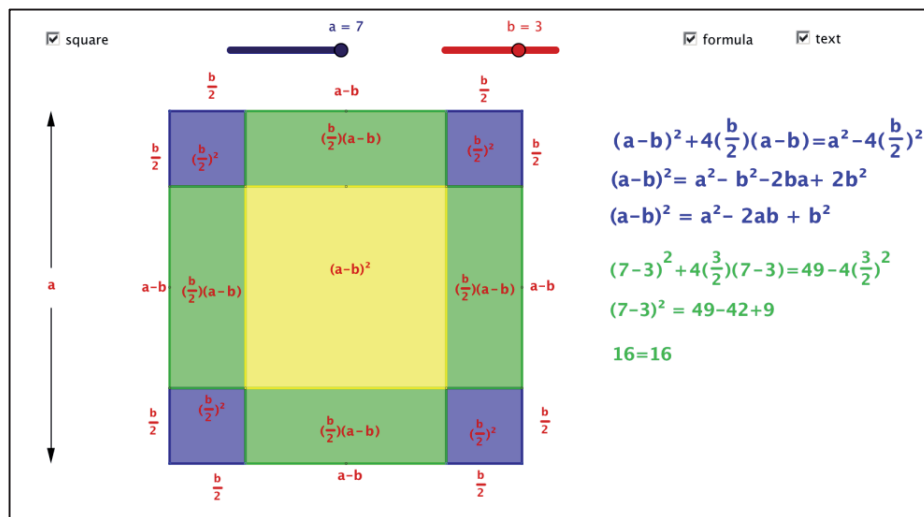


Figure 4.61 Pelin ticked the check boxes

Pelin asked students if there was anyone who didn't understand how they found the extension of  $(a-b)^2$  by the help of the areas. Then she explained one more time with the help of GeoGebra and displayed students the identity is always true for the real numbers. She dragged the slider "a" and "b" to change the numbers dynamically to convince students the equation never changed.

Then she continued with the last  $a^2 - b^2 = (a-b)(a+b)$  identity. She wrote this identity on the board and asked students to model. She gave them two minutes wait time.

*Pelin: Is there any idea? [v.25.40-25.43].*

*Student: We can drive a big square and a small square in it, as we did for previous identity.*

*Pelin: We can try it.*

*Student: Ok*

*Pelin: Lets come to the board and draw your model. [v.27.28-27.32].*

Student came to the board and drew her model. She drew a big square and a small square on it as presented in Figure 4.62.

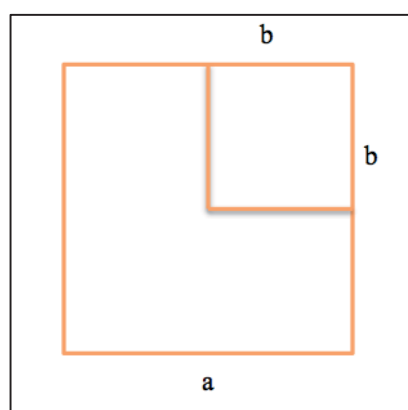


Figure 4.62 Student's model of  $a^2 - b^2$  identity

*Pelin: Can you explain your model?*

*Student: Area of a small square is subtracted from the area of a big square.*

*Pelin: So? Do you mean that identity is difference in the areas of two squares?*

*Student: Right, when we subtract the small square from the big square the rest of it is what we are looking for.*

*Pelin: Does everyone agree? Is there any idea?*

*Students: Agree. Students said in choral.*

*Pelin: I constructed a GeoGebra file related to this identity and I want to show it to you now.*

Then Pelin opened and displayed this identity via GeoGebra. However at that time the electricity power cut off, therefore she couldn't project the screen onto the board. Her laptop's battery was full and she displayed the file from the laptop screen. In order to do this, she divided students into three groups and displayed group by group. First view of the GeoGebra file is presented in Figure 4.63.

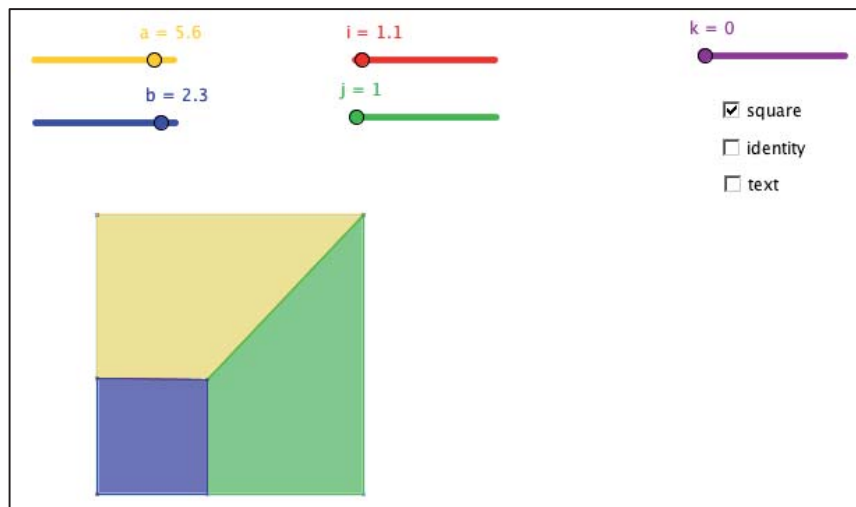


Figure 4.63 First view of Pelin's second activity in third lesson

In the first view Pelin asked students, their interpretation for the meaning of each part. Then she said that a whole shape represents decreasing square, a small square represents ascendant square and two right trapezoids represent the differences between these two squares. Pelin asked if they took out the small square what they have. Then she moved third slider to translate one of the trapezoids out as presented in Figure 4.64.

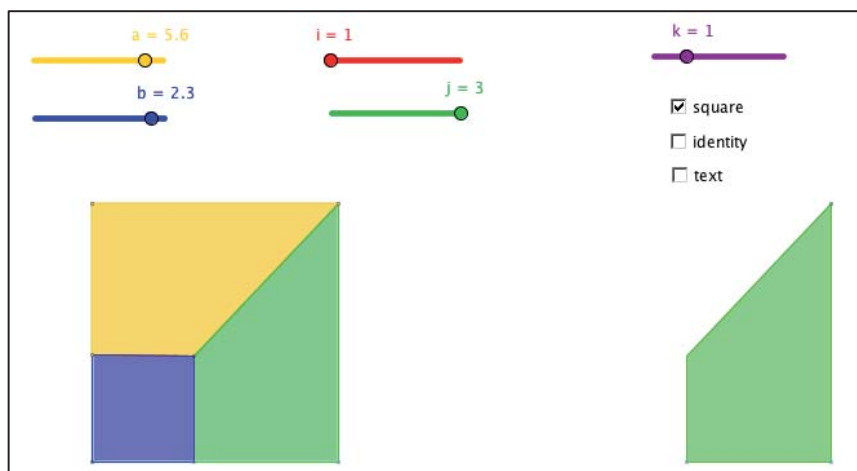


Figure 4.64 First trapezoid was taken out

After that Pelin moved fourth slider to take second trapezoids out as presented in Figure 4.65. Then she said that this shape was the difference between two squares. Pelin asked if students whether they can calculate the area of these shapes.

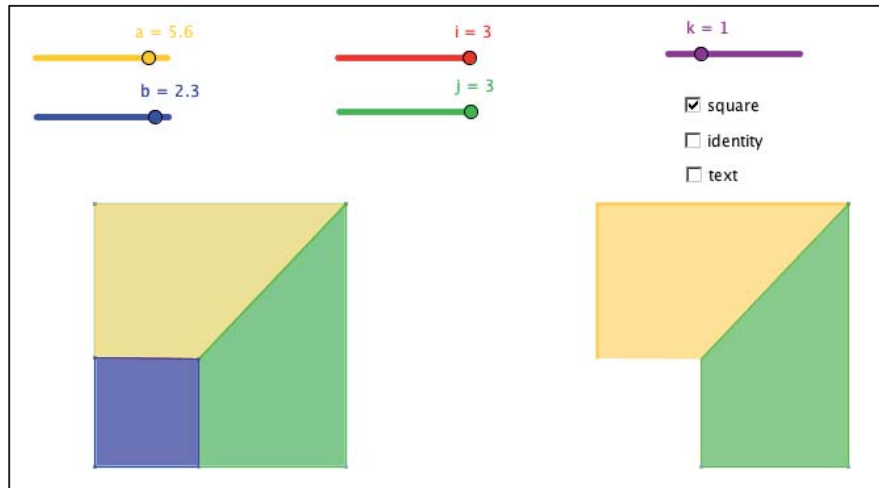


Figure 4.65 Second trapezoid was took out

Pelin asked students whether they have any idea about the area of these shapes. Then she tried to explain how they can construct a rectangular with these two trapezoids. With this aim, she moved one step further the fifth slider to present the Figure 4.66.

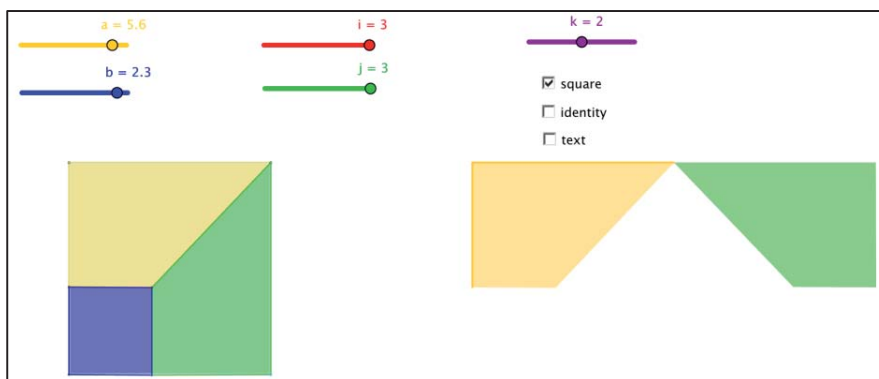


Figure 4.66 The first trapezoid was moved

After that she moved one step further the fifth slider to reflect the first trapezoid around a line passes through mid-points of two sides as presented in Figure 4.67.

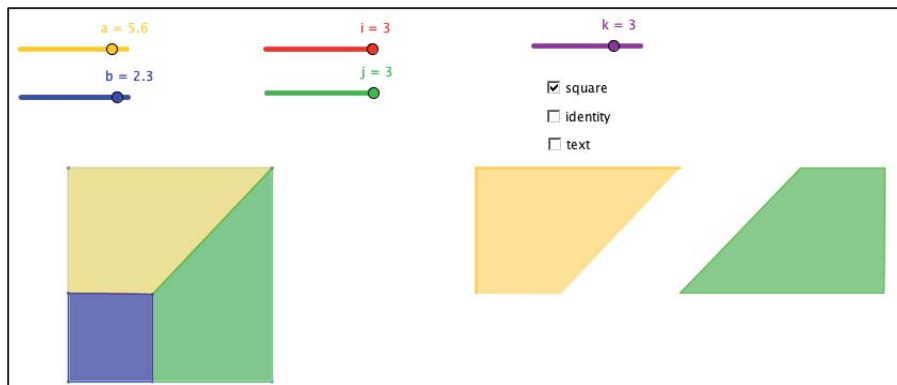


Figure 4.67 Trapezoids were about to jointed.

Finally she moved last step the *fifth* slider to translate first trapezoid towards the second trapezoid and constructed a rectangle as presented in Figure 4.68.

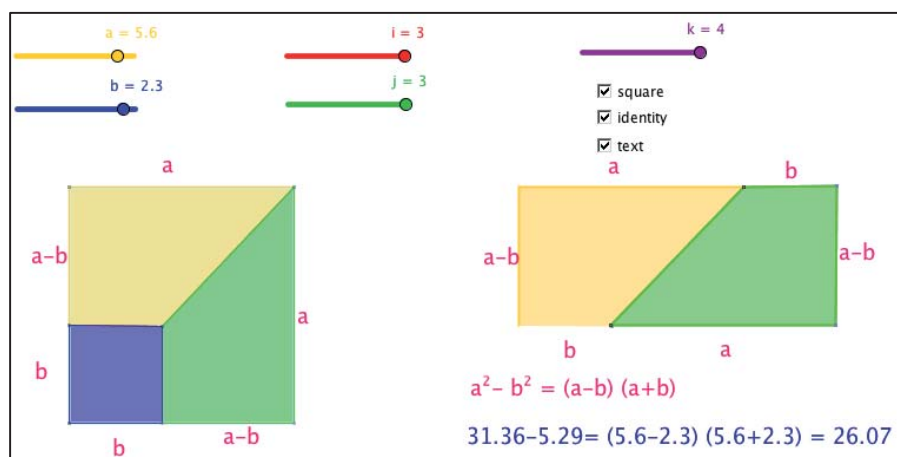


Figure 4.68 Trapezoids constructed a rectangular



The role of Pelin was a guide and she asked questions to challenge students to model  $(a-b)^2$  and  $a^2-b^2$  identities. The dynamic nature of GeoGebra program supported students' reasoning about the geometrical model of  $(a-b)^2$  and  $a^2-b^2$  identities.

Then she ticked the “text” check box and named the each side of the geometrical shapes and “identity” check box to visualize the identity with letters and numbers. After that, she asked how to calculate the area of this rectangle. Her aim was to help students recognize that the area of rectangular was the product of the length of short side of the rectangle which is “a- b” and length of long side which is “a+b” is equal to the differences between two squares area  $(a-b).(a+b) = a^2 - b^2$ .

In this lesson, students' models constructed via paper folding extended the general case of the identity via GeoGebra program.

#### **4.1.2.3.1 Student Reflection**

To evaluate the lesson from students' point of view they were asked to write a reflection paper. The questions for this paper were the same as in the first lesson. During the last five minutes of the class time, she projected the set of reflective questions on the board. Students were asked to write their reflections to the lesson implementation. 23 out of 31 student comments about the lesson were favorable.

At the end of the lesson, Pelin asked students to write a reflection paper, in order to evaluate the lesson from students' point of view. The questions for this paper were the same as in the first lesson.

According to their answers, students were pleased to learn geometrical models of identities via GeoGebra. Thirteen of the students reported that they believe that they understand models of identities with GeoGebra better. One of the student comments was “the models were easy to understand, I learned geometric model of identities with the help of GeoGebra. I didn't need to memorize the rules,” Fourteen of the students drew their attention to the visualization properties of the GeoGebra in their report. One of the

students comments was “visualization is necessary to comprehend these kinds of geometrical rules. Via these models I could galvanize the identities into the life in my mind.” Three of the students reported that learning identities via GeoGebra was so practical. One of the students comments was “It was so practical that teacher could easily change the length of the sides in the model and displayed that inequalities are true for the numbers. This was the difference of the inequalities from equations.” Three of the students reported that using technology in teaching was very useful. Three of the students reported that “I enjoyed this lesson while learning. The dynamic models took my attention and It is really important for teacher to learn how to use it.” Eight of the students reported their complaint from Geogebra. Five of the students report that they didn’t understand what teacher means with these models in GeoGebra. One of the students comments was “I confused during the lesson. I didn’t understand the topic.” Another students’ comments was “I was bored during the lesson. I couldn’t concentrate on the lesson.”

Students discussed algebraic identities in the larger part of the class time to discover the rules. Students reported that educational technology was very helpful for them to reach lesson objectives.

#### **4.1.2.3.2 Pelin’s Third Lesson Performance**

In the third lesson, Pelin’s performance for the C1 was consistent with the advancing level. Pelin’s level for the C1 increased from adapting level to advancing level. Advancing level is the fifth and highest level to use educational technology in teaching. C1 mainly related to the purposes of integrating technology in teaching mathematics. In the third implementation the usage of educational technology was very crucial. The aims of the technology-based activities were explaining the construction of geometrical models of identities. Dynamic models helped students visualize the geometric model of algebraic identities. In this lesson, Pelin used two GeoGebra

activities. In the first activity,  $(a-b)^2$  identity was modeled. In this file there were two squares one was inside the other. Squares side lengths were connected with the sliders, so it was possible to change the side lengths dynamically. The GeoGebra technology procedures concentrated on, dragging sliders to change the length of the sides and observe the balance in  $(a-b)^2$  identity for rational numbers. In the second activity,  $a^2 - b^2$  identity was modeled. In the file, there was a whole shape represents decreasing square, a small square represents ascendant square and two right trapezoid represent the differences between these two squares. There were sliders and check boxes in the file. The sliders were used to subtract trapezoids out from the big square. Another slider was constructed to show the process of how to make a rectangular with two right trapezoids. Difference between squares, showed with the area of two right trapezoids  $(a-b)(a+b)$ . This activity was helpful to visualize the algebraic identities. The dynamic nature of GeoGebra program supported students' visualizations concerning geometrical model of  $(a-b)^2$  and  $a^2 - b^2$  identities. The usage of technology-linked representations helped students extent the concrete case constructed via paper folding to the general case of the identity. Without educational technology it would be more difficult to display geometric models of identities in a dynamic way.

Pelin's performance for the C2 was consistent with the exploring level. Pelin's level for the C2 increased from adapting level to exploring level. C2 mainly related to the PSTs' knowledge of students' understandings, thinking, and learning in technology-based mathematics lesson. *In exploring level, a document provides an environment for students to deliberately take mathematically meaningful actions on objects.* The technology-based activity in this lesson provided an environment to facilitate students' reasoning on the geometrical model of identities. At the beginning of the lesson, Pelin modeled  $(a+b)^2$  identity via paper folding to construct concrete material for the  $(a+b)^2$  identity. Then she asked students model  $(a-b)^2$  identity by paper folding as she did for  $(a+b)^2$  identity. Then Pelin challenged students to construct their models for the  $(a-b)^2$  identity. In order to assist students in modeling process she asked questions and helped

them. Students could construct the  $(a-b)^2$  identity with same logic. Pelin confirmed students' answers and discussed other models suggested by students for  $(a-b)^2$  identity. Then she continued with GeoGebra activities. GeoGebra activities included an action for students to have them observe the geometrical consequences of algebraic identities. Pelin asked questions via technology-based activity and encouraged students to generate conjectures about the geometrical model of identities. The aims of the questions were to have student break geometrical model of the algebraic expressions into parts, determining how the parts relate or interrelate to one another or in an overall structure. Then students verified the geometrical model of  $(a-b)^2$  and  $a^2-b^2$  identities in the dynamic nature of GeoGebra program. However, not all of the students were actively engaged into the class discussion and posed their ideas. She tried to force the rest of the students who observed the activity and didn't answer the inquiry questions to share their ideas.

Pelin's performance for the C3 was consistent with the advancing level. Pelin's level for C3 increased from accepting level to advancing level. C3 mainly related to the PSTs' knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics. In advancing level, *teacher uses technology in a fully constructive way, including tasks for development of higher-level thinking and deepening understanding of mathematics concepts. Technology is strongly aligned with curriculum goals. Technology use is effective for the chosen curriculum topics. The selection of technology-based activity to teach identities was fit with the content.* The subjects of the lesson were algebraic identities. Lesson objective was; the student should be able to represent identities with geometrical models. The design of the lesson well structured. The transition from hands-on activity to technology-based activity was fit with together for students' conceptual understanding. Via hands-on and experimentation of new mathematics ideas, Pelin supported the students' interpretations of the dynamic models of algebraic identities. Then she used technology to represent explicitly and concretely abstract algebraic identities for deepening understanding of these concepts. In

the lesson, students could observe the relationship between geometric models of the algebraic identities in the dynamic nature of the GeoGebra. This helped students interpret the geometric models of any algebraic equations. The technology-based activities that she chose for the lesson was strongly align with the curriculum goals.

Pelin's performance for the C4 was consistent with the exploring level. Pelin's level for C3 increased from adapting level to exploring level. C4 mainly related to the knowledge of instructional strategies and representations for teaching and learning mathematics via technology. In exploring level, *teacher focuses on students thinking about mathematics. Technological activity document is built around learning objects and must explicitly promote student reflection – especially the posing of questions for sense making.* Even if, in the paper folding activity, Pelin used student-centered instruction, while using technology she tried to promote student reflection about identities. Technology-based activity supported her to pose questions to the students to discover geometric meaning of identities. She asked what- if questions such as *what if I asked the geometric model of  $a^2 - b^2 = (a-b)(a+b)$ .* The role of Pelin was a guide and she asked questions to challenge students to model  $(a-b)^2$  and  $a^2 - b^2$  identities. She encouraged students to be active participants in the class and let them draw on their own models for the identities. In addition Pelin was ready for the unexpected situations. When electricity power cut off, she used her backup plan and displayed the file from the laptop screen instead of projecting the screen onto the board. For doing this, she divided students into three groups and displayed group by group to the students. However, limited number of students had a chance to use technology on their own. Computer lab might provide more opportunity for students to work with GeoGebra activities individually.

#### **4.1.2.3.3 Post Interview III**

After implementing the third lesson, Pelin was interviewed to criticize and reflect on the lesson. The PSTs performance to use educational technology in teaching were criticized by themselves in terms of purpose of the activity (cognitively challenging), the role of the teacher (a guide and help students focus on reasoning), and role of the questions (to led students explore mathematical concepts, discover relationship between mathematical concepts).

In her opinion, the usage of educational technology was very essential in this lesson. In one hand, without this technology it was also possible to model these identities via paper folding and cutting as she did at the beginning of the lesson, on the other hand, supporting hands-on activity with technology-based activity providing students an environment to learn conceptually. In this lesson dynamic environment provide students observe the construction of identities and discover their geometrical meaning. She stated that educational technology supported her hands-on activity and helped students discover geometric meaning of algebraic identities. She reported on the main issues that have been discussed in the interview were;

I taught geometrical model of the identities and GeoGebra helped me to visualize the models in dynamical environment. Since I could demonstrate squares visually, it was easy to explain the algebraic meaning of the geometrical models via technology. I could also display that these equations were always true for rational numbers via dynamic equations.”

Pelin considered the drawbacks of previous lessons and implement most professional lesson in the last one.

#### **4.1.2.4 An Overview of Pelin’s Implementations**

Pelin implemented three lessons with sixth and eighth grade students at a public elementary school in Ankara. Pelin’s teaching showed evidence of change in terms of

technology usage levels from the first implementation to the third based on the TPACK levels rubric developed by Lyublinskaya and Tournaki (2011). In her implementations, Pelin chose objectives aligned with the three criteria stated above and employed educational technology as a teaching tool to address mathematics topics in field experience course. These three lesson implementations showed that she has the basic technological, pedagogical and content knowledge to design technology-based activities, and implement in elementary school. Pelin didn't construct any technology-based activity, which required advance technical skills, to create. This might be because of the she has limited technical knowledge to create these activities via technology. In addition, it was possible to implement her all three activities without educational technology via physical manipulatives.

Since Pelin used educational technology with different aims in her three lessons. Brief information was give for each lesson. The combination of technology, pedagogy and content was in basic level in the first lesson. In the first lesson, the usage of educational technology was not very crucial. Technology was not used to teach a specific mathematics concept. The purpose of using educational technology in teaching was only drill and practice. This was a teacher-directed lesson. The nature of the activity wasn't available to ask inquiry questions. The technology-based activity used in the lesson was limited to transfer mathematical content to students via technology. Nevertheless, the technology-based activity was required technical skills to construct via spreadsheets. Pelin constructed this activity by herself. Therefore, Pelin's has technical knowledge to construct a spreadsheet activity. When it is compared with the first lesson the usage of educational technology was very crucial in the second lesson. The technology-based activities used by Pelin in the lessons were fit with the lesson objectives. Although the technology-based activity didn't require advance technical skills to construct, they were applicable to have students reach the lesson objectives.

In the second lesson the combination of technology, pedagogy and content was more professional than previous lesson. She combined technology; pedagogy and

content knowledge to create technology based teaching activities in a way that led students to a deeper and conceptual understanding of mathematics topics. It was a student center lesson. She posed questions to have students' sense with mathematical concepts linked with GeoGebra representations. Students were actively engaged into the class discussions. Students explored triangle inequalities and angle-side relationships via GeoGebra program. To reach the general overview, students shared their ideas about the relationship between these geometrical concepts and tested their conjectures via GeoGebra. After the explorations, students constructed a mathematical conjecture and they were appeared to develop conceptual understanding about these geometrical rules. The selection of technology-based activities to teach mathematics topics was fit with the content in the second implementation. Pelin didn't construct the technology-based activity, which requires advance technical skills to construct by herself for this lesson. Even if Pelin didn't construct the technology-based activity, her combination of technology, pedagogy and content was professional. The way to teach this topic via technology was successful. Pelin used dynamic nature of the GeoGebra program to have students discover geometric meaning of algebraic identities in the third lesson. The selection of technology-based activities to teach this mathematics topic was fit with the content. Her teaching showed evidence that she has basic pedagogical knowledge to transfer mathematical content via GeoGebra technology to the students.

#### **4.1.2.4.1 Last Interview**

At the end of the three technology-based lesson, PSTs were interviewed about their general opinion about using technology in teaching. In the next sections, detailed information of the participants gathered from last interviews was reported. According to Pelin's opinion educational technology is a tool for teacher to help students make abstract mathematical concepts concrete in their mind. She stated that educational technology provides active participation of students into the class discussion. However,



possible technical problems in educational technology cause time consuming. Therefore teachers should take precautions for unexpected situations while designing a technology-based lesson.

In her opinion, in this technology age teaching methods should be mixed with educational technology. She reported that, the technology-based courses in teacher training program, specifically ELE 430 contributed her knowledge to use educational technology in teaching mathematics effectively. After that, technology-based teaching experience helped her to notice her potential to use educational technology in teaching. She believes that from the first implementation to the third there was a progress in her performance. However, she didn't feel ready to teach mathematics via technology in her future teaching. There were two reasons for this idea. First of all, she needs more technology-based courses, which includes technical skills and teaching methods related to effectively usage of educational technology in teaching. She advises teacher-training programs to include more technology-based courses. Secondly, using educational technology in teaching hasn't been very common in our education system, yet. According to her observations in collaborative schools, teacher never use educational technology in their teaching. Students have no idea about dynamic geometry programs, as well. For her second implementation at the beginning of the lesson she spent time to give information about GeoGebra menu. Therefore she had a concerns related to usage of educational technology in her future teaching. To implement technology-based lessons she expects from her future school to include technological equipment, technology user teachers and students. In the interview she stated that, the more she implement technology-based lesson, the more she used educational technology effectively.

The following section includes excerpt from reflection papers of Pelin. In one of the assignments of ELE 435 course, Pelin reflected on her experiences in this study. One of the questions of that assignment required PSTs to write their opinions about the most educative experience for them. Although this study was not a part of the ELE 435 course

In her reflection paper prepared for ELE 430 course Pelin describe her implementations as most educative experiences for her. Related part of her reflection was;

I had lots of good experience by the help of this course. I helped our assistant teacher for her thesis and taught three different subjects in three different times. It was the most educative experience for me. I felt the mood of being a teacher. It was very funny and nice. Being in the center of the scene and teaching was a different feeling. All the control of the class was in my hands. I used technological materials in my lesson so it was hard to tell a subject to students, who had not used any materials in their lessons, by using technological tools. I had to be ready for all unexpected conditions. Thus, it was really good for our progress.”

Pelin’s performance in these three lesson implementations represented in the Figure 4.69.

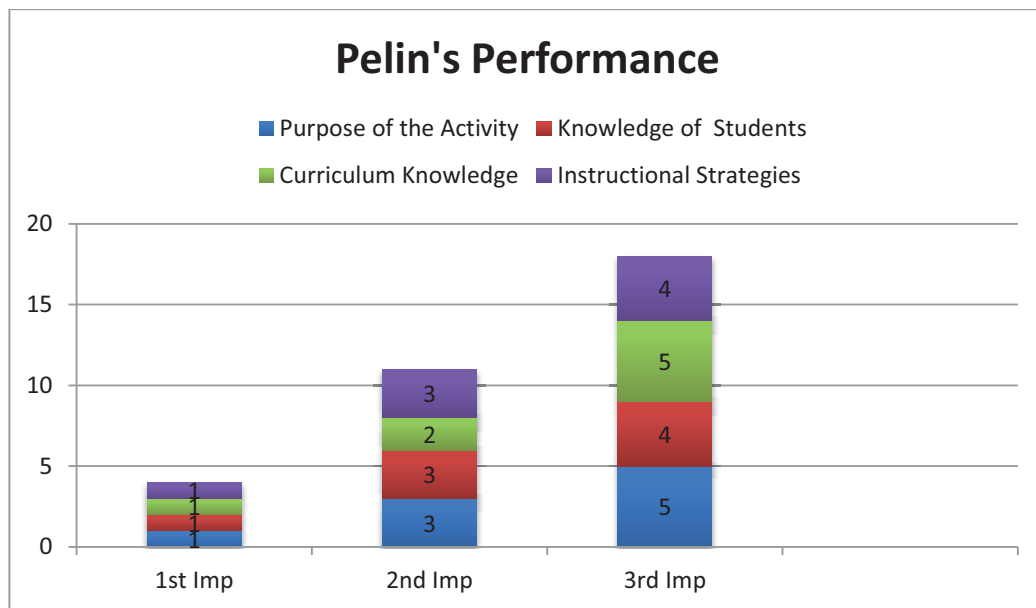


Figure 4.69 Pelin's Performance

### 4.1.3 Case of Ali

This section presents the findings regarding the case of Ali. Findings related to the changes and adaptations observed in Ali in terms of TPACK throughout the implementation of three technology-based lessons during the field experience were explained in the subsequent sections.

#### 4.1.3.1 Findings of Ali's First Implementation

Ali implemented his first lesson with 16, eighth grade students in the classroom at the private school. Class included laptop and smart board as a technological source to implement technology based lesson. The GeoGebra activity that he prepared for the lesson was one of the class activities designed by the university instructor, and constructed by pre-service teachers during the ELE 430 course. He wasn't familiar with the students and classroom environment, since he had never been in that class for

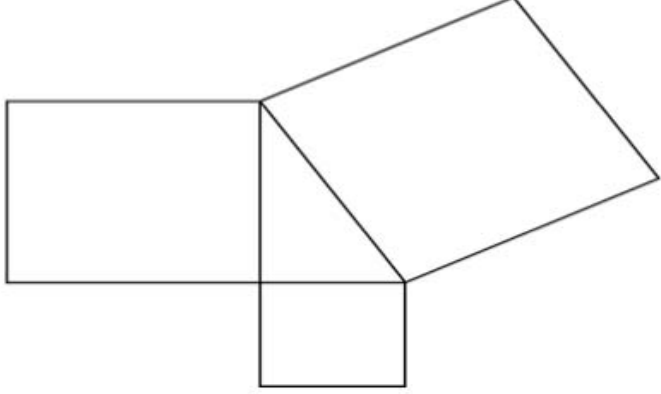
observation in the context of field experience course. The subject of the lesson was Pythagorean Theorem. Lesson objectives were; students will be able to construct geometrical proof of Pythagorean Theorem and students will be able to solve drill, practice and problem related to Pythagorean Theorem. It was traditional geometric illustration for Pythagorean Theorem to display the sum of the areas of the squares whose sides are the two legs is equal to the area of the square whose side is the hypotenuse. Mentor teacher requested Ali to teach this subject to be consistent with official curriculum. The teaching method that he planned to use was discussion. The aim of the technology-based activity was visualize the Pythagorean Theorem dynamically. His goal to use technology in this lesson was to have students discover the relationship between each side in right triangle. Ali planned to be guide in the lesson to have students reach the lesson objectives. Mentor teacher stated that students' have pre-knowledge about basic components of triangles to learn this theorem. However, students have no pre knowledge about dynamic geometry program. Ali felt ready to teach and had no concern about lesson implementation before the lesson. The duration of the lesson was 40 minutes.

At the beginning of the lesson he introduced himself to the students and tell about what mathematics topic he would teach. Then Ali started the lesson by distributing the activity sheets he prepared for students to have them follow his instructions during the lesson as presented in Figure 4.70 Ali would also introduce the GeoGebra program, by focusing on its dynamic features but since he lost 15 minutes at the beginning of the lesson, because of technical problem, he passed this part. He would give some information about Pythagoras as a mathematician and Egyptian pyramids which constructed based on 3,4, 5 right triangle, but he did not.

In this activity sheet, he had constructed a blind presentation of Pythagorean Theorem and asked students fill the missing lengths and areas based on the GeoGebra file during the lesson.

**PİSAGOR TEOREMİ**

**1)** İlk olarak Pisagor teoremini keşfedelim. Aşağıdaki şekle ait uzunluk ve alanları boşluklara yazınız.



$|BC| =$  
 $A(BCEF) =$

$|AC| =$  
 $A(ACDK) =$

$|AB| =$  
 $A(ABGH) =$

**2)** Yukarıda bulduğunuz karelerin alanları arasında nasıl bir ilişki vardır?

$=$ 

 $+$

Figure 4.70 Activity sheet of Ali's first lesson

In this activity sheet there were four more drill questions and two real life problems about the Pythagorean Theorem to assess students understanding.

After distributing the activity sheets, Ali gave a try to open the GeoGebra file. However since the program hadn't been uploaded the classroom laptop, he couldn't open the GeoGebra file. After 15 minutes retardation to fix the problem up, he loaded the program on the laptop from internet. Then he opened the file and visualize the Pythagorean Theorem as presented in Figure 4.71.

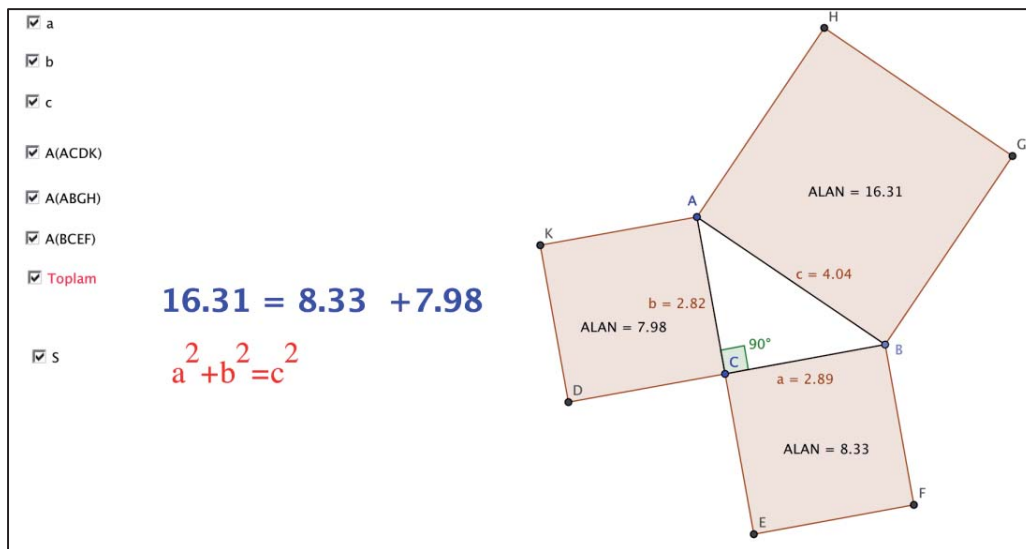


Figure 4.71 Pythagorean Theorem

He ticked all of the boxes one by one to show the each length of the sides in ABC triangle and area of squares. In the GeoGebra file, there was a “16.31 = 8.33 + 7.98” dynamic equation that shows the relationship between areas of the squares. Dragging one of the vertex points of the ACB triangle, Ali changed the length of the sides and so areas. Students had opportunity to see while lengths and areas were changing, the relationship between areas never changed via dynamic equation. Students this equation is always true for the right triangle. Thus, students were aimed to see the relationship between sides of right triangle. Therefore students concluded that sum square of right triangle’s sides equal to square of hypotenuse. In addition to this, the equation of Pythagorean Theorem,  $a^2 + b^2 = c^2$ , was written, where c represents the length of the hypotenuse, and a and b represent the lengths of the other two sides.

After Ali explored the GeoGebra file with students, he wrote the equation of Pythagorean Theorem on the smart board “ $a^2 + b^2 = c^2$ ”. He said “*sum of the areas of the squares whose sides are the two legs is equal to the area of the square whose side is the hypotenuse in the right triangle.*”

Then he asked students to fill the blanks in first question of activity sheet. Students wrote their own length of the right triangle sides and areas in the condition that the values should confirm the Pythagorean Theorem. In the second question students wrote their own equation of Pythagorean Theorem with numbers. After that he gave information about special measurements of Pythagorean Theorem which are 3, 4, 5; 5, 12, 13 and 7, 24, 25 right triangle and asked a question as presented in Figure 4.72.

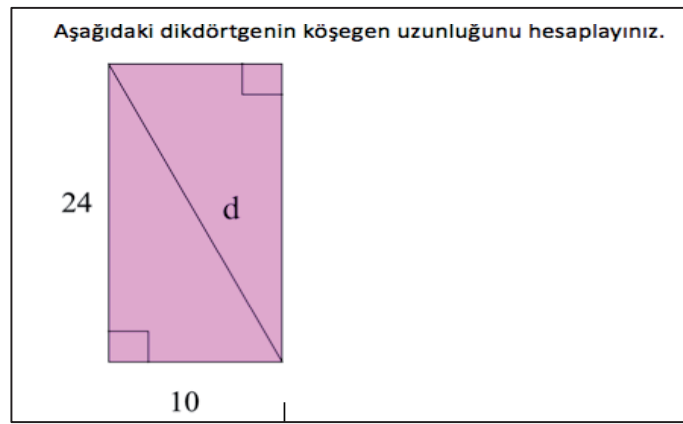


Figure 4.72 Question about 5,12,13 triangle

After 3 minutes wait time he let one of the students to answer the question on the board. Ali asked three more questions about the finding missing side of the right triangle and students solved the questions on the board.

To assess students understanding related to Pythagorean Theorem he asked two real life problems as presented Figure 4.73 and Figure 4.74.

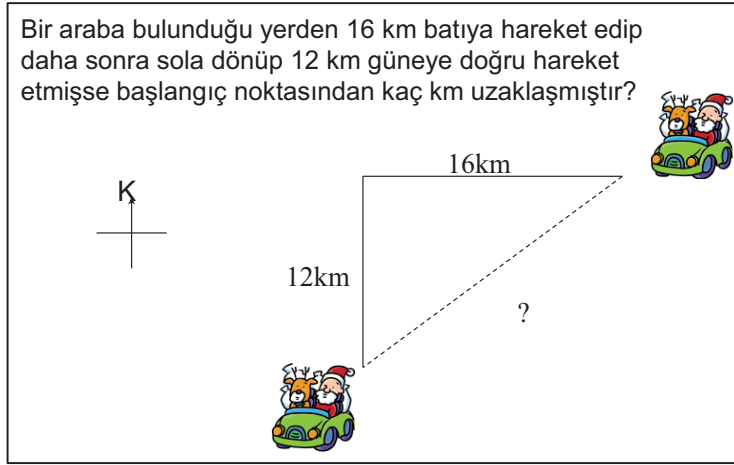


Figure 4.73 Assessment problem one.

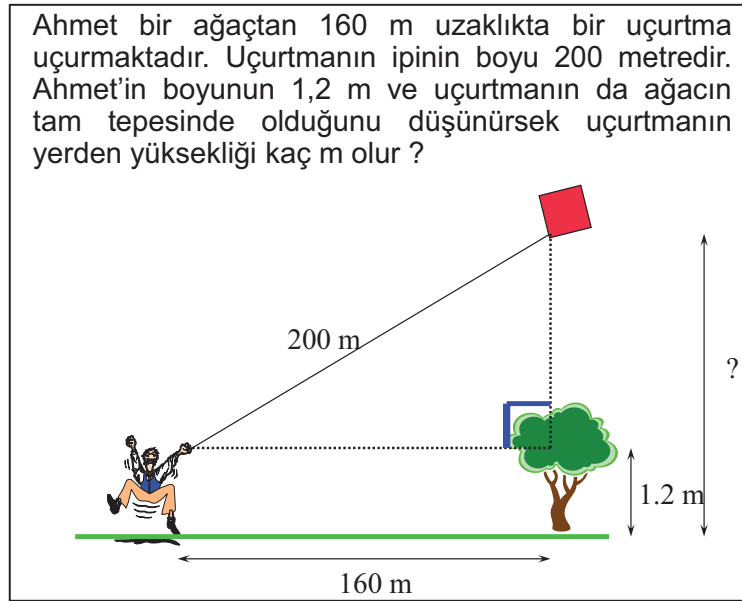


Figure 4.74 Assessment problem two

In this lesson, GeoGebra was used to change the length of the right triangle sides by dragging a vertex point of triangle. This demonstrated that the area of square on the



hypotenuse of a right triangle is equal to the sum of the areas of squares on the two sides. Students observed the model and lengths of the sides and wrote an equation between them as the side lengths changed.

After solving these two assessment problems, Ali asked students whether they have any question about the Pythagorean Theorem. Students said they have no question to ask and he finished the lesson. Then he projected the set of reflective questions stated below on the smart board to have students written their answers about the lesson implementation.

#### **4.1.3.1.1 Students Reflection**

Ali asked students to write a reflection paper, in order to evaluate the lesson from students' point of view. The questions for this paper were;

- 1) What have you learned today's lesson? Explain briefly?
- 2) What do you think about the use of technological tool while learning this geometric issue? Explain your reasons.
- 3) In which part of the lesson you enjoyed?
- 4) In which part of the lesson you bored?
- 5) How do you evaluate your performance in class discussion? What was the most difficult part for you? If you give yourself a score out of 10 what would be this score?
- 6) Is there anything that you want to add related to this lesson?

In their answers for open response survey questions of reflection paper, all of the 16 students' comments about the lesson were favorable. They were pleased to have been taught this topic via GeoGebra. Three of the students reported that GeoGebra was an opportunity to visualize the Pythagorean Theorem. One of the students comments was "I am a visual learner I can learn better if I can see the geometrical concepts. GeoGebra

gave that chance to me. I could observe the relationship between sides of the right triangle.

In general students appreciated learning geometry via GeoGebra. Students were actively engaged in the lesson. They tried to solve the drill and problems that Ali asked in the class.

#### **4.1.3.1.2 Ali's First Lesson Performance**

In the first lesson, Ali's performance for the C1 was consistent with the adapting level. C1 mainly related to the purposes of integrating technology in teaching mathematics. In adapting level, *teacher use technology in a way that is new and different from teaching without this technology (dynamic nature, linked representations) and used for learning new knowledge by students*). In the adapting level, technology is used for teacher demonstrations, which include presenting new knowledge and practice without active explorations. For this lesson, Ali constructed geometrical model of Pythagorean Theorem via GeoGebra program. The constructed geometrical task mirrored the structure of the textbook presentation of the Pythagorean Theorem, rather than making a real proof (i.e. Pythagoras' real proof, Bhaskara's proofs, Garfield's proof, etc.). The purpose of Ali's activity was presenting a dynamic model of Pythagorean Theorem via GeoGebra, rather than proving it. Nevertheless, the usage of technology was essential for this lesson. Without this technology it would be difficult to visualize the Pythagorean Theorem in a dynamic way.

Ali's performance for the C2 was consistent with the accepting level. C2 mainly related to the PSTs' knowledge of students' understandings, thinking, and learning in technology-based mathematics lesson. In accepting level, *technology is mostly used for teacher demonstrations or teacher-led student-follow work with technology; it is rarely used for students' independent explorations*. He demonstrated the geometrical model and explained it directly. There were no experimental activities via GeoGebra to help

students discover the relationship among the lengths of the sides in a right triangle. He didn't ask these questions to support students' conceptual understanding. To promote student knowledge Ali didn't ask any challenging questions as well. His goal was to have students use formula to find the missing sides in right triangle. Students followed the lesson and answer the questions. The large part of class time, Ali used GeoGebra program. Technology rarely used by students since design of the lesson wasn't appropriate for students' independent explorations. Students almost did not use technology to explore math ideas. Instead of making students actually doing mathematics, Ali used GeoGebra to represent a geometric concept.

Ali's performance for the C3 was consistent with the adapting level. C3 mainly related to the PSTs' knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics. The lesson objective was; the students should be able to use Pythagorean Theorem to solve mathematics problems. In adapting level, *the technology is used as a replacement for non-technology based tasks in a traditional curriculum approach*. The technology-based activity that he constructed for Pythagorean Theorem was not real proof. It was a traditional curriculum approach to Pythagorean Theorem. This might because of the he has limited content knowledge to prepare a real proof for Pythagorean Theorem or he has limited technical knowledge to construct Bhaskara's or Garfield's proof via GeoGebra program.

Ali's performance for the C4 was consistent with the accepting level. C4 mainly related to the knowledge of instructional strategies and representations for teaching and learning mathematics via technology. In accepting level, *the instructions are teacher-led. Teacher structures lesson plan with limited student explorations with technology. Technological activity document does not promote student reflection*. In this lesson, Ali used teacher direct approach. The role of Ali in the lesson was a lecturer. Technology provided environment to demonstrate dynamic model of the Pythagorean Theorem. The activity was helpful for students to observe relationship between sides in a right triangle. However, students didn't have a chance to use technology individually and made

exploration. In addition he didn't ask challenging questions to have students think about the model.

#### **4.1.3.1.3 Post Interview I**

After implementing the first lesson, Ali was interviewed to criticize and reflect on the lesson. The PSTs performance to use educational technology in teaching were criticized by themselves in terms of purpose of the activity (cognitively challenging), the role of the teacher (a guide and help students focus on reasoning), and role of the questions (to led students explore mathematical concepts, discover relationship between mathematical concepts).

In his opinion, technology usage was necessary for this lesson. He incorporated technology in teaching subject matter topics to mirror the structure of the textbook presentation of Pythagorean Theorem. Technology-based activity helped him demonstrate the relationship between edges of the right triangle dynamically. He thinks that students understood the logic behind Pythagorean Theorem observing the dynamic activity even without active explorations. However he couldn't create discussion environment to challenge students' opinions. He reported that the questions that he asked were not eligible to have students reasoning about the Pythagorean Theorem. He lectured the theorem with the help of GeoGebra activity and students came up with the Pythagorean Theorem. Students could solve the problems that he prepared to assess students' learning. He stated in the interview;

since, it was my first lesson implementation, I was so excited. I couldn't do exactly what I designed in the lesson plan. To be honest, I couldn't do what I planned in the lesson plan. Normally I would give some information about Egyptian pyramids and Pythagoras to the students however I forgot. [02.30-02.48]. Actually my GeoGebra activity was pretty well prepared to teach this theorem, because it was dynamic and I could change the each sides of the right triangle so the relationship between sides of the right triangle was demonstrated with too many examples. Although I prepared questions previously to have

students find the relationship by themselves, I didn't ask questions to the students during that process. Next time I hope I will control my excitement. I will prepare better lesson plan and I will try to implement the lesson as I planned.

For the next implementation, he would consider drawbacks of this lesson and plan to design more professional a technology based lesson implementation.

#### **4.1.3.2 Findings of Ali's Second Implementation**

Ali implemented his second lesson with 18 sixth grade students in classroom at private school. Class included laptop and smart board to display GeoGebra file to the class. Ali was familiar with the students, since he has been in that class for observation previously in the context of ELE 435 course. The subject of the lesson was definition of decimal numbers. Lesson objective were; students will be able to make a definition of decimal numbers and students will be able to analysis the decimal numbers. Mentor teacher requested Ali to teach his subject to be consistent with official curriculum. However teacher did not provide information about the pre-knowledge of the students. Therefore Ali designed a basic level lesson to teach the definition of decimal numbers and analysis of them. He designed a geometrical model for decimal numbers via GeoGebra. In this file, there was a square, which was divided into 10 columns and each columns divided into 10 equal squares. There were two sliders in the file. The first slider was connected with squares in the first column. When Ali moved the first slider, equal squares of the first column shaded. The second slider was connected with columns. When Ali moved the second slider, columns in the square shaded. There was a check box to divide square into 10 columns or 100 equal squares when it was ticked. Via this GeoGebra file students could see the geometrical model of decimal numbers smaller than 1. With the help of sliders, students could change the decimal part of the number. The teaching method that he planned to use was discussion. The aim of the technology-based activity was having students noticed the definition of decimal numbers via

GeoGebra. Ali planned to be guide in the lesson to have students reach the lesson objectives. Ali felt ready to teach and had no concern about lesson implementation before the lesson. The duration of the lesson was 40 minutes.

At the beginning of the lesson he introduced himself to the students and tell about what mathematics topic he would teach. Then, he started to the lesson, distributing the activity sheets to the students to have them follow his instructions in the lesson. Students have no information about the GeoGebra program, but Ali didn't introduce the GeoGebra menu to the students. He started the lesson. First he asked students;

*Ali: What is decimal number?*

*Student: A number written using the base 10. For example 0,4 is a decimal number.*

*Ali: It is also called decimal fraction. For example, the decimal 0,4 = 4/10.*

*Student: Yes, that is true.*

*Ali: We write decimal numbers using a decimal comma. For example 3.58.*

Then Ali wrote 3.58 on the board and named the decimal comma as presented in Figure 4.75.

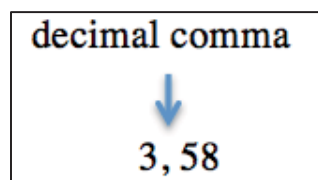


Figure 4.75 Decimal comma

Then, he wrote  $3,58 = \frac{358}{100} = 3 + \frac{5}{10} + \frac{8}{100}$  on the board.

*Ali: When you move right from the decimal comma, each place value is divided by 10.*

He said. After that he asked students to solve first question of activity sheet. First question was related to analysis of natural numbers and it was asked to check student's

pre-knowledge number analyzing. He chose one of the volunteer students to solve the question on the board. Student solved the question and they continued with the second question. Second question was related to constructing of the decimal number, which was 1,32. As presented in Figure 4.76, he gave a model to the students and asked them to shade the necessary parts in the model to construct 1,32 decimal number.

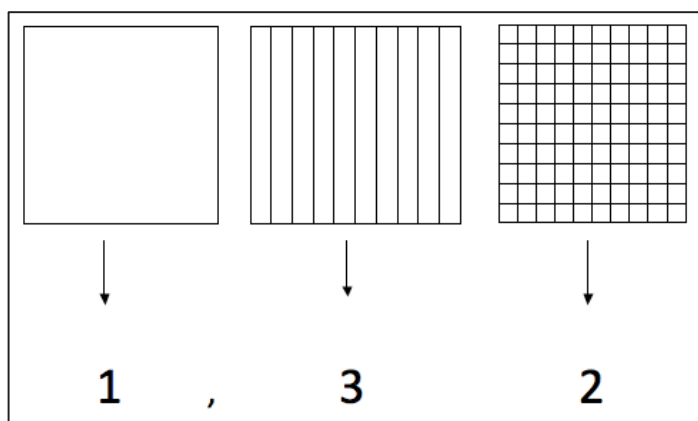


Figure 4.76 Second question

At the beginning students solved the question individually. After 2 minutes wait time, he wrapped around the class and checked students' answer. Then he chose one of the volunteer students to have solved the problem on the board. Student came to the board and drew three squares then she divided second square into 10 column and third square into 100 square. Finally she shaded the first square and three columns from second square and 2 square from third square.

Third question of the activity sheet was related to decimal fraction. In the activity sheet there were three fractions which are  $\frac{24}{100}$ ,  $\frac{2}{25}$  and  $\frac{3}{5}$ . He asked students to convert these three decimal fractions to decimal numbers. Three of the volunteer students came to the board and divide numerator to the denominator and found the solutions. After this, Ali opened the GeoGebra file as presented in Figure 4.77.

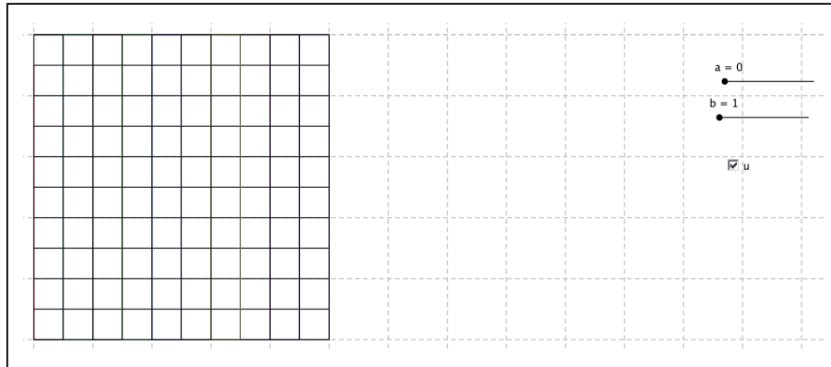


Figure 4.77 First view of Ali's GeoGebra activity in second lesson

Ali displayed Figure 4.78 in GeoGebra file to ask question about the model. Ali asked his first question to the students;

*Ali: Which decimal number is represented in GeoGebra file?*

*Student: It might be 0.04*

*Ali: How do you know this?*

*Student: There are 100 parts and four parts were shaded. It means  $\frac{4}{100}$ .*

*Ali: Yes, you are right.*

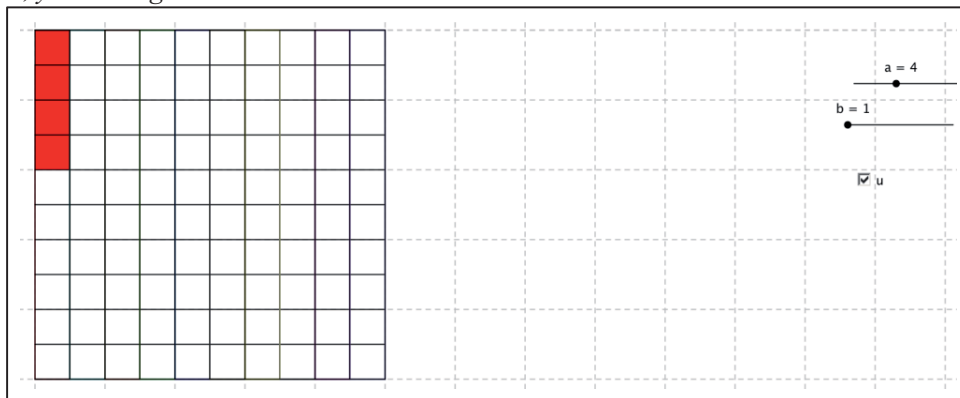


Figure 4.78 A decimal number



Ali moved the first slider up to ten and shaded first column. Then he moved second slider up to three and shaded second and third column as presented in Figure 4.79.

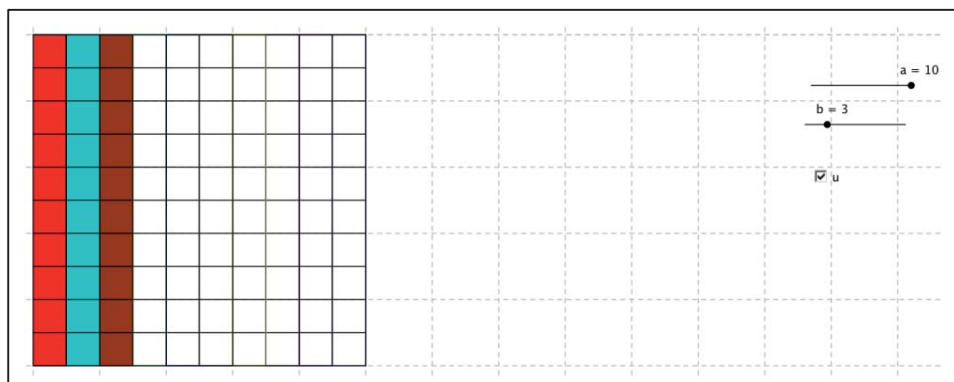


Figure 4.79 Shaded three column

He asked;

*Ali: Could you say the decimal number represented in GeoGebra file?*

*Student: It is 0,3, cause there are 100 parts and 30 parts were shaded. It means  $\frac{30}{100} = \frac{3}{10} = 0,3$ .*

*Ali: Good job.*

Ali moved the second slider up to ten and shaded the whole square as presented in Figure 4.80.

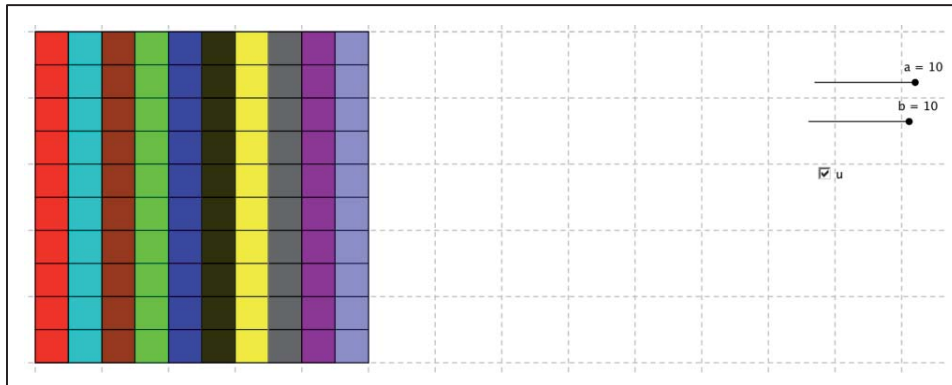


Figure 4.80 Shaded whole square

He asked;

*Ali: Could you say the decimal number represented in GeoGebra file?*

*Student: It is 0,3, cause, there are 100 parts and 30 parts were shaded. It means  $\frac{30}{100} = \frac{3}{10} = 0,3$ .*

*Ali: Yes it is true, well done.*

Then he clicked on the “u” check box as presented in Figure 4.81 and asked students;

*Ali: Well, how many small squares are there in one column?*

*Student: Ten.*

*Ali: Is there anyone who wants to explain this model?*

*Student: It is easy to see that, it is a whole consist of 10 columns and each column has ten small squares. Therefore whole is 100 small squares.*

*Ali: Perfect. First column represent hundredths, and the rest of the columns represents tenths of the decimal numbers.*

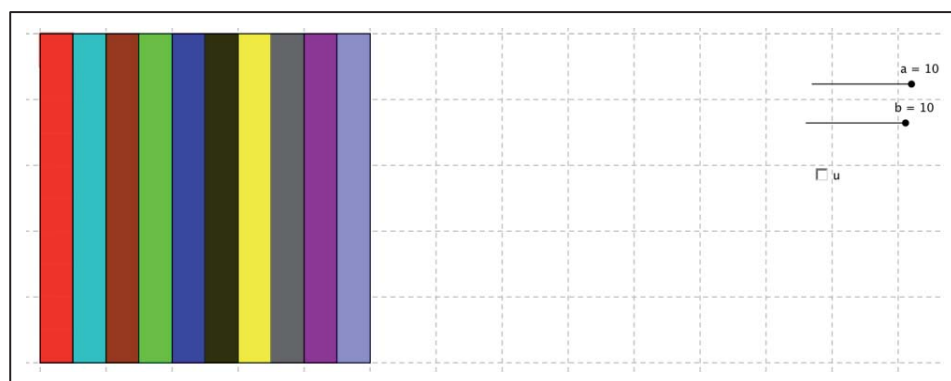


Figure 4.81 Last view of Ali's GeoGebra activity in second lesson

Ali finished the lesson and the bell has been rung. There was not enough time to have students' reflections about the lesson.

Up to now technology activities included inquiry tasks. Ali engaged students into the class discussion via asking questions about the GeoGebra task. Students created a conjecture about the decimal numbers.

#### 4.1.3.2.1 Alis's Second Lesson Performance

In second lesson, Ali's performance for the C1 was consistent with the adapting level. Ali's level for C1 remained at the same level. C1 mainly related to the purposes of integrating technology in teaching mathematics. In this lesson Ali constructed a dynamic model for decimal numbers, which are smaller than one via GeoGebra program. The purpose of using educational technology was to represent the geometrical models of decimal numbers. In adapting level, *teacher use technology in a way that is new and different from teaching without this technology (dynamic nature, linked representations) and used for learning new knowledge by students*. The constructed geometrical task mirrored the structure of the textbook presentation of the decimal numbers. The GeoGebra activity provided students a dynamic environment to help create geometrical model of different decimal numbers between 0 and 1. Without this technology it would

be difficult to represent tenths and hundredths of the decimal numbers in a dynamic model.

Ali's performance for the C2 was consistent with the adapting level. Ali's level for the C2 increased from accepting level to adapting level. C2 mainly related to the PSTs' knowledge of students' understandings, thinking, and learning in technology-based mathematics lesson. In the lesson, Ali focused on students' thinking of how to model a decimal number. The task constructed by Ali for the decimal numbers via GeoGebra was well structured. He could construct dynamic models for decimal numbers. With the help of dynamic point, he could change the model. In the Adapting level technology-based activities include inquiry tasks, and the teacher poses questions for sense making. In the lesson, Ali asked questions to help students think about the geometrical models of the decimal numbers, *how many squares they need to shade to create a model for a decimal number? How many more shaded square they need to add or delete to create another decimal number?* By this way students compared the two decimal numbers based on their models. His goal was to have students construct meaning from the geometrical models about decimal numbers. Active participation of students was encouraged by Ali via choosing different students to answer. However, the questions were so easy for students' that they could answer all the questions with no hesitation. Ali should have information about students' pre-knowledge about decimal numbers from the math teacher, but he didn't.

Ali's performance for the C3 was consistent with the exploring level. Ali's level for C3 increased from adapting level to exploring level. C3 mainly related to the PSTs' knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics. The lesson objective for this lesson was; the students should be able to construct a model for given decimal number. Technology was aligned with lesson objective. He constructed a GeoGebra task that decimal numbers can be modeled. However, technology-based activity was limited with the decimal numbers between 0

and 1. Ali needs to add one or two square to represent whole and model bigger decimal numbers than one or two.

Ali's performance for the C4 was consistent with the adapting level. Ali's level for the C4 increased from accepting level to adapting level. C4 mainly related to the knowledge of instructional strategies and representations for teaching and learning mathematics via technology. In adapting level, *technological activity document is built around learning objects but does not promote student reflection – especially the posing of questions for sense-making*. In this lesson, Ali used teacher led instructional strategy to have students make judgments about the decimal numbers. In adapting level, educational technology provides a dynamic environment for students to do mathematics with teacher guidance. Ali served as a guide to support student investigations related to models of decimal numbers. He gave attention to the questions that he asked to have students reasoning about the geometrical model of decimal numbers. However, students have pre-knowledge about decimal numbers that they could easily answer all the questions that Ali asked. Therefore, Ali couldn't create a discussion environment in the lesson.

#### **4.1.3.2.2 Post Interview II**

After implementing the third lesson, Ali was interviewed to criticize and reflect on the lesson. The PSTs performance to use educational technology in teaching were criticized by themselves in terms of purpose of the activity (cognitively challenging), the role of the teacher (a guide and help students focus on reasoning), and role of the questions (to led students explore mathematical concepts, discover relationship between mathematical concepts).

In his opinion, technology usage was necessary for this lesson since technology helped him construct a dynamic model for the decimal numbers. Students observed the

dynamic model of the numbers and made a comparison between their magnitudes. After the lesson in the interview he stated that,

in this lesson I feel more comfortable myself in the classroom. I could control my excitement better than previous lesson. I think this time I used GeoGebra activity more effectively. I tried to allow students to discover the meaning of the geometrical model of the decimal numbers by asking questions. I aimed with these questions to have them examine the geometrical model of the decimal numbers by observing the models for different decimal numbers. Students could easily answer the all questions surprisingly. However this might be because of the their pre-knowledge. Next time I am planning to maintain my performance in this lesson. The aim of my activity will be teaching a mathematical concept conceptually.

#### **4.1.3.3 Findings of Ali's Third Implementation**

Ali implemented his third lesson via GeoGebra program with the same 15 eighth grade students with whom he implemented his first lesson in a classroom at a private school. Class included laptop and smart board to display GeoGebra file to the students. Ali prepared the GeoGebra activity specific for this lesson implementation. He was familiar with the students and classroom environment, since he implemented his first lesson with this class and had already been in that class for observation previously in the content of ELE 435 course. The subjects of the lesson were factorization; factorization via greatest common factor, factorization by grouping and factorization of quadratic equations and geometric model of quadratic equation Lesson objectives were; students will be able to factorize the equations based on greatest common factor; students will be able to factorize equations by grouping and students will be able to factorize quadratic equations and students will be able to construct a geometric model for quadratic equation. Mentor teacher requested Ali to teach this subject to be consistent with official curriculum. The teaching method that he planned to use was discussion. He constructed a GeoGebra file for factorization of a quadratic equation. The aim of the technology-based activity was visualize the geometric model of  $2x^2 + 5x + 2$  quadratic equation. His

goal to use technology in this lesson was to provide students an example to make them sense with factorization of quadratic equations. The mentor teacher stated that students' had pre-knowledge to learn this topic. Students were familiar with GeoGebra program from Ali's first implementation. Ali planned to be a guide in the lesson to have students reached the lesson objectives. Ali felt ready to teach since he prepared GeoGebra activity before the lesson but had some concern about the implementation of lesson. The constructed GeoGebra activity was the geometrical model of the  $2x^2 + 5x + 2$  quadratic equation. In this file there were seven slider connected with the geometrical shapes. These shapes came together and construct a rectangular whose sides are  $2x+1$  and  $x+2$ . The area of the rectangular was equal to  $2x^2 + 5x + 2$ . These shapes were two squares whose sides were  $x$  and represented  $2x^2$ , five rectangular whose sides were  $x$  and  $1$  and represented  $5x$ , two units represented  $2$ . Totally there were 9 geometrical shapes. From these shapes, two squares were joined together and connected with a slider, four of the rectangles were connected with the sliders  $g$ ,  $r$ ,  $f$  and  $u$ , the other rectangle located onto the center and it was stable, two units were connected with the sliders  $k$  and  $s$ . When the slider is moved, the connected geometrical shapes pulled away from each other. In addition to these, there was a check box to show the name of the sides. Via this GeoGebra file, students could see the geometrical model of  $2x^2 + 5x + 2$ . With the help of sliders, students could move the geometrical shapes and put them together then constructed the model of  $2x^2 + 5x + 2$ . Via, this GeoGebra activity, students see that the area of the whole shape  $(2x+1) \cdot (x+2)$  doesn't change even if you separate the parts of it. The area is equal to total area of the parts' which is  $2x^2 + 5x + 2$ . The duration of the lesson was 40 minutes.

At the beginning of the lesson Ali introduce the topic that he would teach. Then he distributed the activity sheets, which included the problems to be completed in that lesson. First three questions were related to greatest common factor. To explain the solution of these questions he didn't use technology. The questions were to factor the expressions  $4x^2 + 5x$ ,  $6ab - 2b$  and  $x^3 - x^2 + x$ . After factoring these problems he

continued with the fourth question. Fourth question was modeling the factors of  $x^2 + 4x + 4$ . For this question he distributed algebra tiles to the students. He introduced the parts of algebra tiles to the students as presented in Figure 4.82.

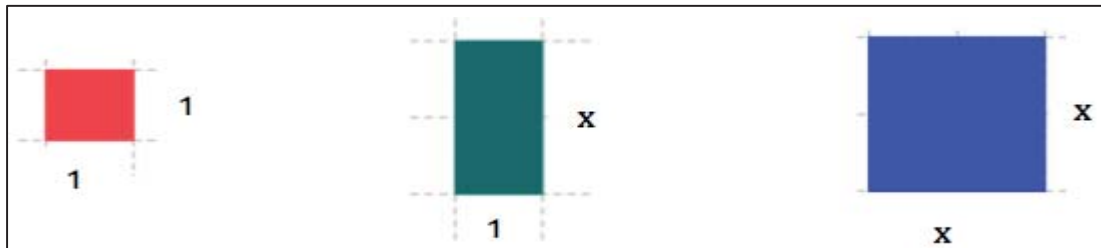


Figure 4.82 Algebra tiles

Then he asked.

*Ali: Can you calculate the area of each part?*

*Student: What is the unit of measure?*

*Ali: Oh sorry it is cm.*

*Student: Then the first one is 1cm.  $1\text{cm} = 1\text{cm}^2$*

*Ali: You are right. What about second one?*

*Student:  $x\text{cm}.1\text{cm} = x\text{cm}^2$*

*Ali: Who wants to calculate the last one?*

*Student:  $x\text{cm}.x\text{cm} = x^2\text{cm}^2$*

*Ali: You are all right thank you. Now can you calculate the sum of the areas?*

*Student: Yeah, we can add all of the results and find the result I think.*

*Ali: Let's do it.*

Student came to the board and wrote the answer of the question, which is  $x^2+x+1$

*Ali: Is he right?*

*Students: Yes.*



Up to now, Ali had students complete a hands-on experimental activity with algebra tiles. With the help of algebra tiles, students generated conjectures to model algebraic expressions. While working with the tiles, Ali asked students to compare similarities and differences between their algebraic models of algebraic equations.

Then Ali continued with asking students to construct a geometrical model for  $2x^2 + 5x + 2 = 0$  quadratic equation. Ali asked students to construct the algebraic expression  $2x^2 + 5x + 2$  with the algebra tiles. Five minutes later he wanted students to share their ideas.

*Ali: Which of the parts did you used?*

*Students: All of them were necessary to construct this algebraic expression.*

*Ali: How many  $x^2$  did you use?*

*Student: I used two  $x^2$  to construct  $2x^2$ .*

*Ali: What about the others?*

*Student: I used 5 x to construct  $5x$  and 2 unit for 2.*

*Ali: Yes that is true. Then which geometrical shape did you construct with all these parts?*

*Student: It is little bit complicated. I am trying to do a rectangle.*

*Student: Ye I did rectangles.*

One of the students had made a rectangular model for  $2x^2 + 5x + 2$ .

Ali checked his work and showed to the class. However most of the students could not construct a model. Ali took students' attention and said.

*Ali: I construct a model for  $2x^2 + 5x + 2$  for you with the help of GeoGebra. Let me display it to you.*

He opened the GeoGebra file and displayed the geometrical shapes as presented in Figure 4.83.

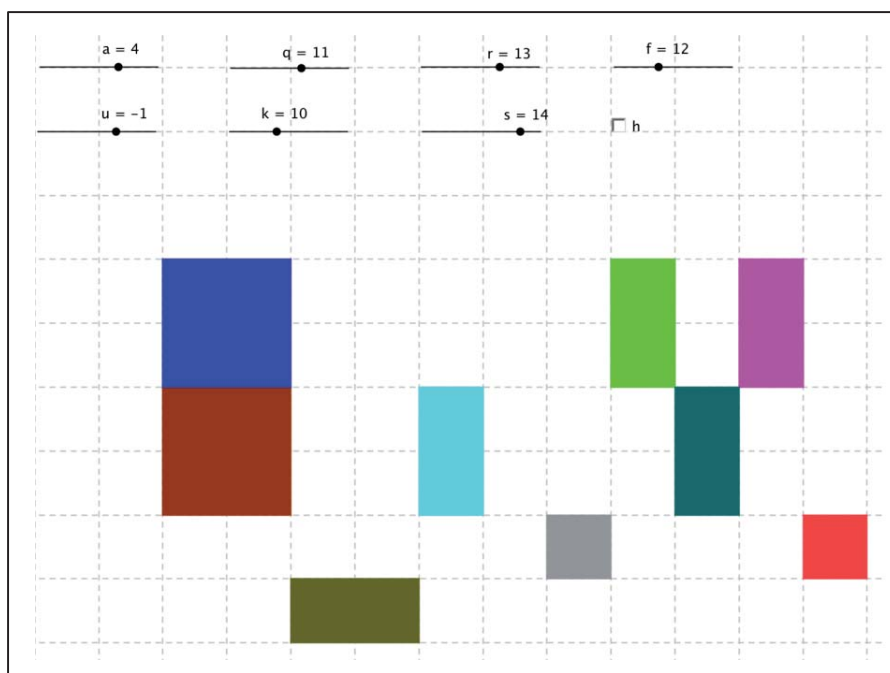


Figure 4.83 Geometric shapes

Ali said that;

*Ali: Now I want to show you how I construct a geometrical model for  $2x^2 + 5x + 2$ . Could you tell me these geometrical shapes and their areas.*

*Student: We have two  $x^2$ , five  $x$ , and two unit.*

*Ali: Lets check if you are right.*

Ali ticked the check box and named the sides of the geometrical shapes as presented in Figure 4.84.

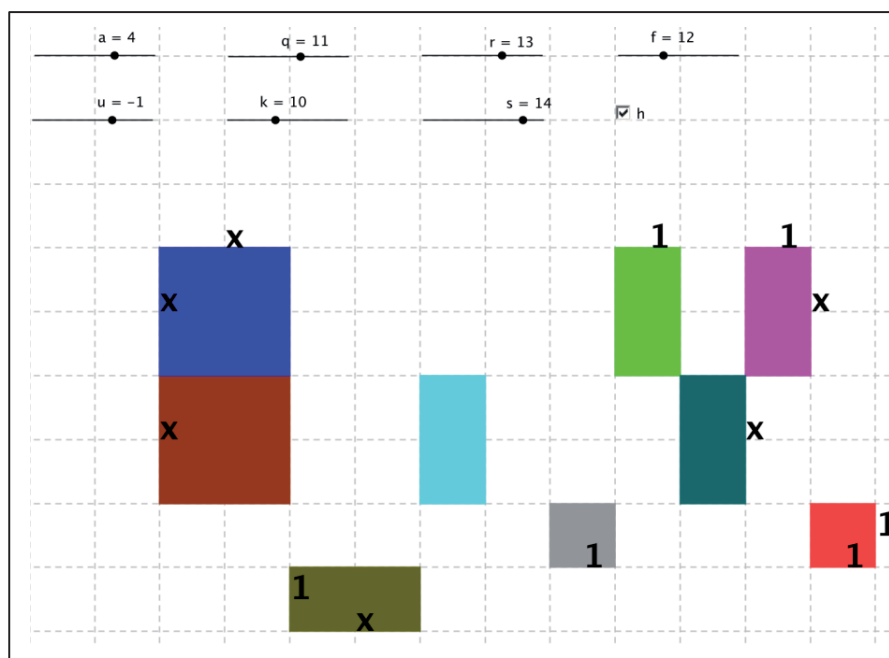


Figure 4.84 Named the sides of the geometric shapes

After that Ali moved the sliders and put the geometrical shapes together as presented in Figure 4.85.

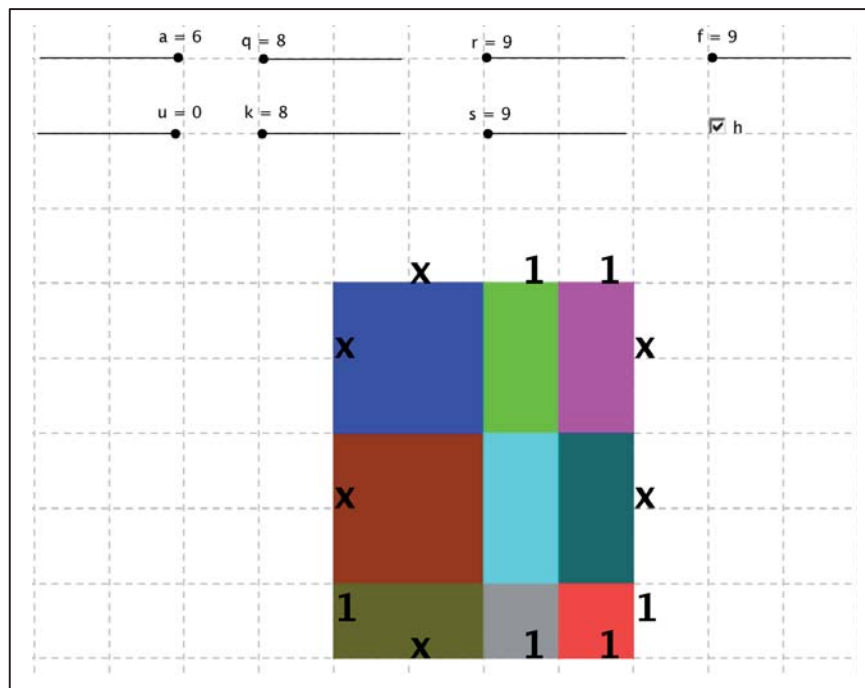


Figure 4.85 Jointed geometric shapes

Student: Actually my model was a little bit different from your model.

Ali: What is the difference?

Student: I located units one on the top of the other instead side by side.

Ali: This makes any change?

Student: I do not think so.

Ali: Is there any different model.

Student: Yes, my model is little bit different from yours as well? I located two  $x^2$  horizontally, but it won't make any change in sum of the areas.

Ali: Oh well, there may be difference between models, but total area never change. Can you tell me the sides of the rectangular?

Student: The long side is  $x+x+1$  and the short side is  $x+1+1$ . I mean the long side is  $2x+1$  and the short side is  $x+2$ .

Ali: How can we calculate the area of the rectangular?

Student: The multiplication of  $(2x+1)$  and  $(x+2)$  is the area of this rectangular.

Ali: Well, can you write an equality about this rectangular?

Student: What kind of equality?

Ali: Umm.. We firstly discussed about the parts of this model.

He moved the sliders and separated the parts of the model.

Ali: Did you remember?

Students: Yeap.

*Ali: Then we put them together, didn't we?*

*Students: Yes.*

*Ali: Do you think is there any difference in the total area of the geometrical shapes.*

*Student: No.*

*Ali: Can you explain why?*

*Student: We just moved the sliders to put them together and separate them. There couldn't be any change.*

*Ali: Ok then, can you write an equation about the area of the geometrical shapes now?*

*Student: At the beginning geometrical shapes were separate from each other and the sum of the areas was  $2x^2+5x+2$ . Then we put them together and constructed a rectangular. The area of rectangular is  $(2x+1).(x+2)$ . Therefore the equation is  $2x^2+5x+2 = (2x+1).(x+2)$ .*

*Ali: Congrats that is true. Could you write the equation on the board?*

*Student came and wrote the equation on the board.*

*Ali: Do you want me to explain once again?*

*Students: No, we got it.*

Ali asked students to compare their models with the model constructed in the GeoGebra file. Some of the students' models were not fit with this model. This created a discussion between students. Students came up with the parts of the algebraic equation could be locate in different places, nevertheless, all models demonstrate the same algebraic equation. Then, the bell rang to end the class. There was not enough time to have students' write their reflections to the lesson.

#### **4.1.3.3.1 Ali's Third Lesson Performance**

In the third lesson, Ali's performance for the C1 was consistent with the adapting level. Ali's level for C1 remained at the same level. Adapting level is the third level to use educational technology in teaching. C1 mainly related to the purposes of integrating technology in teaching mathematics. For this lesson, Ali prepared a technology-based activity via GeoGebra program to teach geometric model of the algebraic expressions. The purpose of Ali's activity was to use dynamic nature of the GeoGebra program to have students observe the geometrical model of  $2x^2 + 5x + 2$  quadratic expression. *In adapting level teacher use technology in a way that is new and different from teaching without this technology (dynamic nature, linked representations) and used for learning*

*new knowledge by students*). The constructed GeoGebra activity gave students an example about geometrical model of a quadratic expression. By dragging the sliders in the GeoGebra activity, Ali could factorize  $2x^2 + 5x + 2$  quadratic expressions. Students observed the activity and answered the questions that Ali asked related to factorization. GeoGebra program provide students a visual environment to compare their models that they constructed with physical manipulative at the beginning of the lesson. Students see that they can switch the parts of the model and it represents same quadratic expression. In this lesson Ali used educational technology in a way that is new and different from teaching without this technology (dynamic nature, linked representations). The usage of technology was essential for this lesson. Without this technology it would be difficult to model  $2x^2 + 5x + 2$  quadratic equation in a dynamic way.

Ali's performance for the C2 was consistent with the exploring level. Ali's level for the C2 increased from adapting level to exploring level. C2 mainly related to the PSTs' knowledge of students' understandings, thinking, and learning in technology-based mathematics lesson. In the lesson, Ali facilitated students' thinking via visualization of quadratic equation. *In exploring level, a document provides an environment for students to deliberately take mathematically meaningful actions on objects.* At the beginning, Ali had students construct algebraic expressions via physical manipulatives. Students can locate the parts of the expression. Ali asked questions to the students to help them analyze the geometrical model of  $a^2$  is a square whose side is  $a$ ,  $bx$  is a rectangular whose sides are  $b$  and  $x$  and constant number can be constructed with the units. His helped students reflect on how the parts related to one another and to create an overall structure about the geometrical model of algebraic expressions. It is difficult for students to make a generalization about geometric models of decimal numbers with a unique example. Nevertheless, GeoGebra activity gave students an idea about geometric model of quadratic equations. Then he supported his teaching via GeoGebra activity.

Ali's performance for the C3 was consistent with the exploring level. Ali's level for C3 remained at the same level. C3 mainly related to the PSTs' knowledge of

curriculum and curricular materials that integrate technology in learning and teaching mathematics. In exploring level, *technology is aligned with curriculum goals. Teacher chooses important topics of school mathematics curricula and technology use is appropriate for the chosen curriculum topics.* The lesson objective for this lesson was; the students should be able to model quadratic equations. In this lesson, technology was aligned with lesson objective. In this lesson, he constructed an activity via GeoGebra program to give an example to geometrical model a quadratic expression. In exploring level, *students are given problem-solving tasks with technology and are asked to expand math ideas on the basis of technology explorations.* GeoGebra program provide students a visual environment to compare their models constructed with physical manipulative. However, technology-based activity was limited with the  $2x^2 + 5x + 2 = 0$  equation. There was no way to construct the model of other quadratic equations via GeoGebra activity because the number of dynamic tiles was specific to this expression. Since GeoGebra file represented only one model for quadratic equation, it is difficult for students to make a generalization about geometric models of quadratic equations. Nevertheless, GeoGebra activity gave students an idea about geometric model of quadratic equations. Students see that they can switch the parts of the model and it represents same quadratic expression.

Ali's performance for the C4 was consistent with the adapting level. Ali's level for C3 remained at the same level. C4 mainly related to the knowledge of instructional strategies and representations for teaching and learning mathematics via technology. In adapting level, *teacher uses various instructional strategies (deductive and inductive) and focuses on students thinking about mathematics. Teacher's use of technology is beyond traditional approaches to curricular topics. Technological activity document is built around learning objects and must explicitly promote student reflection – especially the posing of questions for sense-making.* In this lesson, the role of the Ali was a guide to promote students' reflections and making sense with mathematical concepts via GeoGebra. Ali used discussion teaching method. He asked students to compare their

model with the model in GeoGebra file. This created a discussion environment and gave students share the similarities and differences between their models that could be made for  $2x^2 + 5x + 2$  quadratic expression and came up with that the might be different models. Then he supported his teaching via GeoGebra activity.

#### **4.1.3.3.2 Post Interview III**

After implementing the third lesson, Ali was interviewed to criticize and reflect on the lesson. The PSTs performance to use educational technology in teaching were criticized by themselves in terms of purpose of the activity (cognitively challenging), the role of the teacher (a guide and help students focus on reasoning), and role of the questions (to led students explore mathematical concepts, discover relationship between mathematical concepts).

In his opinion, the usage of educational technology was necessary in this lesson. Without this technology it was also possible to model quadratic equations via algebra tiles, nevertheless, supporting students' visualization via technology-based activity provides students an environment to learn conceptually. In this lesson students observe the dynamic model of a quadratic equation and discover their geometrical meaning. He reported on the main issues that have been discussed in the interview were;

in third lesson I did feel so much better in terms of excitement when I compare previous ones. I think I am getting used to be a teacher. In this lesson I stressed the area model of quadratic equations. At the beginning of the lesson, I asked questions to have them construct a model with physical manipulative and then I demonstrate the model via GeoGebra. GeoGebra was helpful for me to explain the parts of quadratic equation. It was easy to separate the parts and bring together with the help of sliders. It was so practical for me to demonstrate the model and explain it. I do use GeoGebra program in my professional life.

In this lesson Ali had considered the drawbacks of previous lesson and implemented more professional lesson, however this was not enough to increase his level of using educational technology in teaching from adapting level to exploring level



or advancing level. Since students did not use larger part of the technology, this implementation was not accepted at exploring level. Although he supported his technology-based activity with physical manipulatives since, the created GeoGebra activity had some limitations it was not in advancing level. The activity, was not available to model all quadratic equations, it is available for only one quadratic equation.

#### **4.1.3.4 An Overview of Ali's Implementations**

Ali implemented three lessons at a private elementary school in Ankara. Ali's teaching showed evidence of change in terms of technology usage levels from the first implementation, to the third based on the TPACK levels rubric developed by Lyublinskaya and Tournaki (2011). Ali used GeoGebra software to address mathematics topics by employing GeoGebra as a teaching tool. He combined technology; pedagogy and content knowledge to construct technology based teaching activities in a way that led students to a deeper and conceptual understanding of mathematics topics. These three lesson implementations showed that he has the basic technological, pedagogical and content knowledge to design technology-based activities, and implemented them in elementary school environment.

In his implementations, Ali engaged technologic investigations in geometry content and organized pedagogical methods to implement his lessons. Throughout the lesson implementations, he tried to explain mathematical concepts with their models via GeoGebra program. In these activities, Ali's focus was on visualizing the geometrical models of the mathematical concepts. However, each of the lessons has a limitation in the combination of technology, pedagogy and content. In the first lesson, the constructed geometrical model of Pythagorean theorem was not a real proof. In the second lesson, the constructed geometrical model of decimal numbers was limited with the decimal numbers between 0 and 1. In the third lesson the constructed geometrical model of quadratic equations was limited with the  $2x^2 + 5x + 2 = 0$ .

Another drawback of the lesson implementations was the questions that he planned to ask. Although, he planned to ask challenging questions to have students think about the model, he skipped these questions especially at the first lesson. Then during the post interviews he endorsed the importance of the questions he paid attention to the ask all of the questions that he planned. Another drawback of the implementations was the time of the usage of technology. Larger part of class time, Ali used GeoGebra program to visualize mathematical concepts and students almost did not use technology to explore math ideas. Nevertheless, after the lesson implementations, he recognized the drawbacks of the lessons and improved his teaching skills via educational technology.

#### **4.1.3.4.1 Last Interview**

At the end of the three technology-based lesson, PSTs were interviewed about their general opinion about using technology in teaching. In the next sections, detailed information of the participants gathered from last interviews was reported. Before university education Ali interested in any kind of technology. After he took technology-based courses he improved his ability to use educational technology in teaching effectively. He had no teaching experience in real classroom context previously. The three lessons that he implemented for this study were the first time that he had been a teacher in real classroom to teach mathematics. In Ali's opinion, technology is practical tool for mathematic lesson. In one hand, he believes that teachers should learn how to use educational technology specific for their teaching area, on the other hand, he believes that teacher don't need to use educational technology in every single mathematics subject to teach, since some subjects are more appropriate to teach via physical manipulative i.e. place value can be taught via ten blocks. In his opinion, using technology in teaching brings some technical problems with it. Teacher should have necessary knowledge to get rid of these problems otherwise it turns into a time wasting.

He reported that, after this experience, he improved his techno-pedagogical knowledge and ready to teach mathematics via technology.

In addition, in one of the assignments of ELE 420 Practice Teaching in Elementary Education course, that he took one term later from the implementations of this study Ali reflected on his experiences in this study. The assignment was Self-Improvement Paper. In this paper it is expected from PSTs to identify an aspect of their teaching behaviors that they want to improve. Then, write an analysis of the existing situation with this aspect of his or her teaching behaviors and explain their plan about his or her self-improvement on this issue. In Ali's self-improvement paper he identified his ability in using and incorporating the educational technology into the mathematics education. The following section includes excerpts from self-improvement papers of Ali. In the paper he mentioned about the implementations that he did for this study. The related part of his paper is;

for example, in geometry there are dynamic programs that provide students a wide point of view in understanding basic concept. One of these programs is GeoGebra. I took that course last year and it was really beneficial for my professional experience as a teacher. I prepared my activities related to both geometry and other subjects in mathematics. I also used that program in school experience in Bilim College in first semester and students really loved it. For the now, I am not excellent user of GeoGebra but I can create the activities that I need in instruction. For example, I have created an activity such that, you can fill a pool using sliders. I had used this activity to teach fractions and decimals in real classroom context. In order to teach the place value concept in decimals and to teach the equivalent fractions, it was a useful activity. Developing my skills in GeoGebra is not difficult for me because I was engaged with it in a long time. The most effective way to improve my skills in GeoGebra is using it continuously. So, I am planning to use this program in my teaching when I become a math teacher next year.

Ali's performance in these three lesson implementations represented in the Figure 4.86.

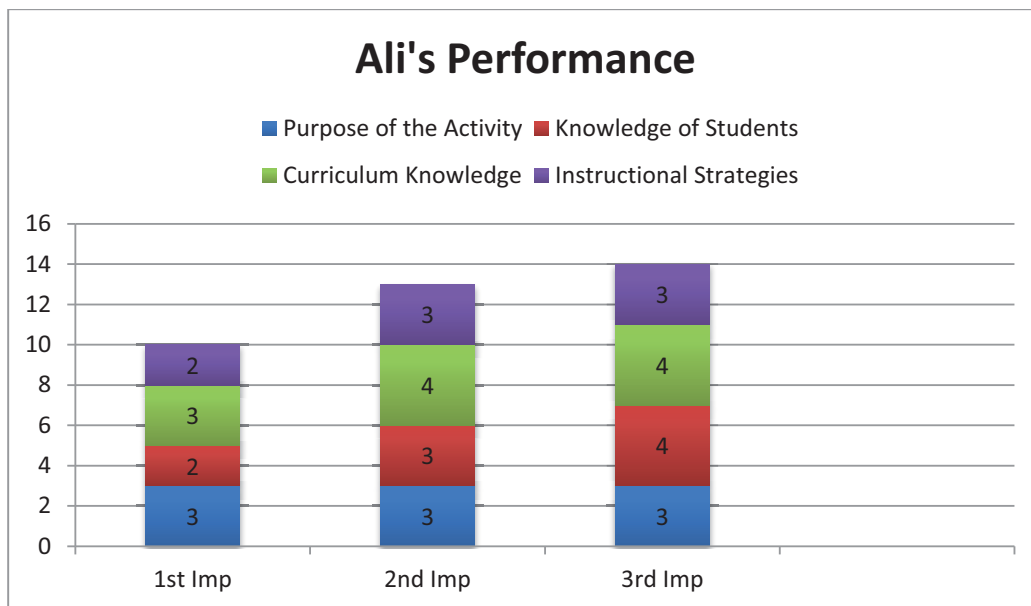


Figure 4.86 Ali's performance

## 4.2 Findings of Research Question III

Findings of the PSTs interpretations of their technology-based lesson implementations process were documented in this part of the study. To identify interpretations of PSTs to technology based lesson implementations final interview data were analyzed. After analysis, to enrich the description of the themes, each of the identified categories is followed by two to four theme items and selected quotes (with time stamps) from the interviews. *Italic font is used to highlight excerpts from interviews.* The following section the categories and their themes that emerged from the data were presented. The thirteen themes emerged in the final interview and classified into three categories. The categories and their themes were (1) the lesson preparation (students' pre-knowledge, lesson objective, location, necessity of the technology, motivation), (2) process of implementation (tool, teacher role, activity sheet, classroom

management, time management, implementation), and (3) mentorship (having a facilitator, and recommendation).

The first category was lesson preparation. The first theme that runs through the entire interview related to lesson preparation category was the students' pre-knowledge. The necessity of having information about students' prior knowledge appeared in each of the interviews. PSTs commented on the impact of not having a good understanding of the students' knowledge when designing and implementing a technology-based lesson. Since learning new knowledge depends on pre-knowledge, having information about what students know about that mathematics topics and can do with educational technology might help teacher design educational activities that consistent with students' strengths and weaknesses. This theme identified by one item, which was;

- Need to know student's pre-knowledge,

The following excerpt related to pre-knowledge was;

Basically, we need to have information about students' pre-knowledge to prepare effective technology-based lesson plan. (Pelin)

Just because I didn't know students' pre-knowledge, my lesson implementation was not effective. Students had already known the mathematical topic. It was not a challenging activity for them. Without any reasoning, they answered the questions. (Ali)

Ali was referring to his second lesson implementation where he taught definition of decimal numbers. He designed a geometrical model for decimal numbers via GeoGebra. However he did not have information about student's pre-knowledge his technological activity was a basic level for students. Students could easily answer the questions related to activity. It wasn't a challenging lesson for students.

Next remaining theme identified by two items was lesson objective. Lesson objective points what students had been expected to be able to accomplish after the

lesson is completed. PSTs stated that at the beginning of the lesson teacher should inform students about the objective, thus students know what is expected from them in the content of that lesson. Lesson objective should be clear and written in a single sentence to be understood. This category identified by two theme items. The two items that emerged related to lesson objective were:

- Focus on one mathematical concept
- Focus on concepts more than technology.

The following excerpts related to lesson objective were;

Students should be informed about what they are going to learn in that lesson. In technology-based lesson our primarily goal is reaching lesson objectives not to teach how to use educational technology. (Pelin)

In a technology-based lesson our aim is have student reach the lesson objective we need to focus on one objective; otherwise, as we see from my implementation, it makes students confused. In addition, teaching mathematical concept should be teachers' first priority and then technology. (Ali)

Ali was referring to his third lesson implementation where he taught three objectives related to factorization. That lesson covered greatest common factor, factoring by grouping and factoring quadratic polynomials. His GeoGebra activity was constructed to teach factorization of quadratic polynomials. He reported during the interview that some of the students appeared to be confused because of learning three objectives in a single lesson and had some difficulties to focus on mathematics concepts. PSTs stated that to set lesson objective, teachers need to consider two points. First one is to effectively integrate educational technology into mathematics education; teachers need to focus on one mathematical objective. Second one is the priority should be teaching mathematical concepts than educational technology.

The third theme identified in the data was related to deciding the location of the technology based lesson implementation; classroom or computer lab. The PSTs stated that aim of the lesson is an important indicator to decide which place is more applicable to implement a technology-based lesson. Being in computer lab is not better than being in classroom every time. In the lesson, if students need to create technological activity by themselves to reach lesson objective, then it is better to implement lesson in computer lab. If students need to observe the activity, it is better to implement lesson in classroom. The item that emerged related to location of the implementation was:

- Decide location of the implementation based on the aim of the technological activity.

The following excerpt related to location of the implementation was;

In my opinion, the location of the lesson implementation, depends on the aim of technological activity. In my lesson to discover the rules by themselves, students should be in computer lab. (Pelin)

Pelin was referring to her second lesson where she implemented in computer lab. That lesson covered triangle inequalities. In the lesson, she asked to discover the rules for triangle inequalities based on experiment they did via GeoGebra in lab environment. Since students needed to be make experiments and observe the relationship, it was better being in computer lab for this lesson.

The fourth theme identified in the data was necessity of the technology. The PSTs stated teacher need to use educational technology when it is mathematically necessary. For example to model a real life problem, visualize a three dimensional object, reflect, translate or transform a geometrical concepts, graph a function, draw geometric meaning of algebraic equations, calculate etc. The item that emerged related to necessity of educational technology was:

- Use technology if it is mathematically necessary,

The following excerpt related to necessity of educational technology was;

I think, we should use technology when it is necessary to teach a geometrical concept. Otherwise it increases teachers' workload redundantly. (Ali)

To refrain from over loading of work force, PSTs use technology when it is essential to teach a mathematical concept.

The fifth category appeared in each of the interviews was named motivation. PSTs stated that students appeared to be motivated to the lesson when they use educational technology.

The theme item that came out related to motivation was;

- GeoGebra take students' attention to the lesson and motivate them to learn

The following excerpts are related to motivation:

In addition students measure the lengths and change the sizes of geometrical objects, this provides motivation for students, I believe. (Merve)

Via GeoGebra, students can use various colors and different line styles this also motivate them to construct geometrical objects. (Ali)

Since educational technology gives students an accurate results and a quick feedback, technology have a positive effect on student motivation I think. (Pelin)

Pelin was referring to her first lesson implementation where she taught operations in decimal numbers. Her goal to use educational technology was motivate students to calculate the operations and check their answers. The activity included the button to show the results of the operations. After students solve the drill and practice, they checked the correctness of results via this technology.

The second category generated strong reaction and appeared in each of the interviews was process of implementation. The first theme that runs through the



interviews related to process of implementation was named Tool Use. PSTs defined educational technology as a tool for teachers to promote students' learning. The items that came out related to tool use were;

- Technology was helpful tool to visualize mathematical concepts and relationship between them,
- Technology helps teacher to design activity sheet for students. Teachers use technology to draw visual objects,
- Technology is a tool for teachers to have students make mathematical proof,
- Technology is a tool for teachers to have students make experiment to discover features of mathematical concepts,
- Technology is a tool for teachers to support students' reasoning and conceptual understanding,
- Technology is a tool for teachers to justify students' ideas about the mathematical concepts being discussed,
- Technology is a tool for teachers to help students transfer their previous knowledge to learn new concepts.

Issues that emerged with regard to visualization were considered the technology is a tool for visualization. The PSTs stated that GeoGebra program provide opportunity to visualize the mathematical concepts. The following excerpt was related to visualization;

Technology allows teacher to connect mathematical concepts with the sliders and while students are moving the sliders they can observe the relationship between concepts visually. I think, it helps students to focus more on the meaning of mathematical ideas. (Merve)

The technological activity in my lesson provided an opportunity for students to visualize identities that could lead to success in conceptual understanding I think. Student dynamically visualize the geometrical meaning of algebraic equations

and they do not need to memorize the identities I believe, whenever they need to this information they can draw the geometrical model and see the rules. (Pelin)

Pelin was referring to her third lesson implementation where she taught identities. Her GeoGebra activity included geometrical model of algebraic identities. She reported during the interview that students appeared to be comprehended the visual models of identities without memorizing. Another example, in Ali's third implementation, he modelled algebra tiles via GeoGebra and taught factoring quadratic expressions. With the help of GeoGebra, students could visualize  $2x^2 + 5x + 2$  and its factors.

One of the advantages of GeoGebra program is allowing teacher to have students internalize mathematical proofs. Students have a chance to work with different examples and make a generalization to proof. The PSTs stated that GeoGebra program provide opportunity for students to make experiment and discover mathematical proof.

The following excerpt related to proof was;

I think it is a helpful tool for mathematics teachers when they want to have students discover geometric objects. Teacher can design an activity via GeoGebra for students to observe and discover features of geometric concept. For example, one of the GeoGebra features that can be used was hiding objects. It gives an opportunity for teachers to hide something and let students discover (Ali)

With the help of my activity students could observe in which circumstances the area of two triangles is equal. Since students had the chance to measure the area and change the length of the edge, they could easily see the in which condition the area of two triangles is equal. (Meltem)

Meltem was referring to her first lesson implementation where she verified the area of triangles, which have the equal base line and height, are equal. She reported in the post interview that students appeared to be comprehended the visual models of mathematical rules without memorizing. In addition, PSTs stated that, technology is a tool for teachers to test students' proposals related to solution for the problem or any

other mathematical issues. In this way students could check the accuracy of their proposal and justify their solutions. The related excerpt was followed;

In my third lesson, students could control their proposal for the solution of the problem, and they can see whether it is true or not. If it is not true they have an idea about why it is not a correct proposal with the help of GeoGebra. (Meltem)

Educational technology helps students transfer their previous knowledge to learn new concepts,

In my third implementation, students could transfer their knowledge, they learned in previous lesson, to another problem situation while drawing a circle when only three points to pass through are given. (Meltem)

Meltem was referring her second implementation, she asked the students to find the circumcenter of a dynamic triangle first by dragging a point (that was connected to the three vertices). This was followed by an exploration of the use of the perpendicular bisectors of each side of the triangle to find the circumcenter of the given triangle. In Meltem's third implementation, she asked students to create a circle when only three points to pass through were given. In the second step of the activity, a few of the students made a connection with the previous lesson and found the correct solution for the problem (this was observed in the video tape of this lesson).

The second theme that also generated strong reaction when it appeared in each of the interviews was named Teacher Role. Two of the PSTs specifically mention the role of the teacher as a guide in technology base lesson. The items that emerged related to teacher role were:

- Teacher role in a technology-based lesson is a guide to help students learn via technology.
- Educational technology assists teachers to use questioning and problem solving teaching methods in mathematics lesson.

The following excerpts are related to teacher role in technology-based classroom environment.

In traditional teaching methods, teacher used direct instruction and students are passive listeners. I think technology give chance students to explore mathematical concepts. During this time teacher role is guide students via questions to help them find their way. (Ali)

In technology-based classroom, teacher is a guide to challenge students with questions while students work with technology. Teachers' aim should be to have students orientate the solution of the questions. Teachers need to give this chance to the students to construct their learning by themselves. (Meltem)

Meltem was referring to her role in lesson implementations. In her three lessons she used problem solving teaching method and behaved as a guide in the lesson. In her opinion, teacher needs to find the ways to challenge students and facilitate their explorations in mathematics. In the lessons Meltem, used technology as a teaching and learning tool to have students reach the lesson objectives with the help of GeoGebra.

The third theme of the process of implementation was Activity Sheet. The PSTs stated that teacher needs to prepare activity sheets for students to have them follow the steps of technological activity. The two items that emerged related to activity sheet were:

- Prepare activity sheet to have students follow the instruction,
- Activity sheet keep student alert with the lesson.

The following excerpts related to activity sheet were;

To explain each step of the technological activity to the students, teacher needs to prepare an activity sheet. (Meltem)

I prepared activity sheets all for my lessons. I did not need to repeat number of times the instructions and questions. Students could follow the lesson easier. (Ali)

Ali was referring to his first lesson implementation where he taught Pythagorean Theorem. For this lesson Ali prepared an activity sheets to have students follow the instruction step by step. Activity sheet included a blind presentation of Pythagorean Theorem. Ali asked students fill the missing parts with the help of GeoGebra file that he prepared for use with activity sheet.

Classroom Management is the fourth theme. PSTs said that when they compare with traditional lessons, educational technology makes classroom management harder. The two items that came out related to classroom management were:

- Technical problems make classroom management harder,
- Following students is more difficult in technology-based classroom.

The following excerpts related to classroom management were;

Most of the classroom management problems arose from technical problems. When I compare with traditional instruction, using GeoGebra and following students at the same time is more difficult than traditional methods. (Meltem)

Meltem was referring to her second lesson where she implemented the lesson in computer lab. The purpose of lesson was to have students determine the circumcenter of a triangle and construct the relationship; circumcenter of an acute triangle is inside the triangle, circumcenter of a right triangle is on its hypotenuse and circumcenter of an obtuse triangle is outside the triangle. In the lesson she had students made judgments based on their exploration via GeoGebra through checking and critiquing. During this time there was a classroom management problem to follow all students at the same time in lab environment.

Time management is the fifth theme that identified. Participants mentioned the time saving features of educational technology in the interview. PSTs stated that, if there

is no technical problem, educational technology helps teacher use time efficiently. The two items categorized as time management were:

- Technology helps PST use time economically,
- Have a backup plan in case of any technical problems.

I think when we use technology in math education, it provides time saving. Since students can draw geometrical objects easily, doing such things with hand takes more time and energy. (Ali)

The teacher, who uses educational technology in their lesson, should be careful. He should check technological devices and activity files before the lesson. He should be ready for possible technical problems and he should have knowledge about the technological device to solve the technical problems” [21.19-22.50]. Next time I will take my laptop with me in case any technical problem and I hope I won’t forget to introduce lesson objectives and dynamic geometry program to the students to save time. (Ali)

Technology prevents the time consuming while constructing the shapes, but all the time we need to have a plan B in case of any technical or other problems. (Pelin)

In some cases, the technology saved time. For example, in Meltem’s first implementation she was able to demonstrate how to make a triangle with the same area by dragging one of the vertex points of the polygon (instead of drawing on the board for each situation). In other cases, technology problems wasted class time. In Pelin’s third implementation, the electricity cut off and she couldn’t project the screen onto the board. Nevertheless, her laptop battery was full and she displayed the GeoGebra file via laptop screen by grouping students into the three parts.

Implementation was the sixth theme of process of implementation category. During the interviews, PSTs reported contributions of the implementation experience to their future teaching. PSTs reported an increase in their confidence in teaching and predicting what students might ask. The items that related to implementation were:

- The more they implement lessons in a real classroom context, the more the PSTs have self-confidence in teaching,
- The more implementations in real classroom contexts, the more PSTs interpret what will happen in the lesson,
- The more implementation in real classroom contexts, the more the PSTs see their strength and weaknesses,
- PSTs' personal reflections to lesson implementation

The more we have teaching experiences in real classrooms, the more we have knowledge about students' reactions.... As a teacher, I feel more comfortable in real classroom environment now. (Meltem)

In the third implementation I could predict what kind of questions students will ask me, about the task. (Ali)

Luckily all of the class activities that I implemented in real classroom context were really close to what I imagine while designing... Normally I thought that I could not implement what I planned, since I am looking for ideal students that have mathematical content knowledge very deeply as a pre-knowledge and they will answer whatever I asked to them related to content. (Meltem)

There is an improvement in my opinion. My best implementation was the last one. (Ali)

In the interviews, participants of the study reported contributions of technology based lesson implementation experience on their professional development. The participants of the study appreciated having this experience before their graduation.

The third category was mentorship. The first theme that emerged from the data was having a facilitator. While it was not anticipated, this theme is in alignment with the SiTI guideline "assist in application." The PSTs commented on the feedback and advice offered by the researcher in her role as a facilitator. PSTs stated that assist in application process was an opportunity to discuss the positive and negative aspect of the lesson and

have an improvement plan for the next implementation. The three items that emerged related to facilitator were:

- Having a facilitator is helpful to improve lesson plan.
- Having a facilitator is necessary to reflect on lesson implementation to grown as professionals.

While I was creating GeoGebra activities, I took your opinions about in which part of the lesson I need to use that activity ... Based on our discussion during the interviews I made some changes in my lesson plan. (Ali)

In the interviews, participants reported that discussing the lesson plan and implementation were helpful for them to improve their lessons for the next time.

The second theme of the mentorship was recommendations. The last question of the interview was: do you have any recommendation about training teachers in terms of using technology? PSTs gave recommendations to the teacher training programs. The four remaining items that came out related to recommendation were:

- Teacher training programs should have more technology courses,
- Integrate technology into methods course,
- PSTs should improve their techno pedagogical skills before graduation,
- PSTs need more lesson plan implementations in real classroom contexts to have more experiences before graduation.

The following excerpt related to implementation was;

There should be more obligatory courses about educational technology in our national teacher training programs. (Pelin)

Teacher training programs need to integrate technology into method course. (Ali)

I need more experiences in real classroom context before graduation. (Ali)



At the end of the study, PSTs provided recommendations based on their experiences to the teacher education programs. PSTs emphasized the importance of technology in teacher education.

A summary of the three categories and the themes identified in the final interview is presented in the Table 5.1.

Table 4.1 Category and Themes

| Category                  | Themes                      | Explanation                                                                                                                                                                      |
|---------------------------|-----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Lesson Preparation        | Students' Pre-Knowledge     | The first criterion that should be considered before constructing a technology-based activity                                                                                    |
|                           | Lesson Objective            | Lesson objective should be compatible with educational technology                                                                                                                |
|                           | Location                    | Will the lesson be taught better in the classroom or the computer lab?                                                                                                           |
|                           | Necessity of the Technology | Why and how to use educational technology                                                                                                                                        |
|                           | Motivation*                 | Technology motivates students to explore mathematical ideas                                                                                                                      |
| Process of Implementation | Tool*                       | Technology is just a tool to support teaching. Visualization is the common reason to use educational technology in mathematics education                                         |
|                           | Teacher Role*               | Guide                                                                                                                                                                            |
|                           | Activity Sheet              | Directions for students necessary to keep them focused on both the topic and the technology-based activity                                                                       |
|                           | Classroom Management*       | Teacher should be more alert in terms of classroom management in technology-based lessons                                                                                        |
|                           | Time Management*            | Teacher should have a back-up plan in case of any technical problems                                                                                                             |
|                           | Implementation Experience*  | The number of lessons is important in order to make a changes in TPACK (at least three)                                                                                          |
| Mentorship                | Having a facilitator        | Reflection-on-action process helps to change in TPACK                                                                                                                            |
|                           | Recommendation              | Technology-based courses, technology-based lessons in the field and reflection-on action processes as well as reflection papers should be included in teacher education programs |

Note. A star mark in the categories stands for a strong overlap with the observation data

## **CHAPTER V**

### **DISCUSSION AND CONCLUSION**

This chapter presents the discussion of the findings of the research study. Present study investigated the change in PSTs' TPACK within the context of field experience and their interpretations to implementing technology based mathematics lessons. This chapter covers the two main sections; the discussion on noticed issues with respect to evidences of change in PSTs' TPACK while using educational technology in teaching based on the TPACK levels rubric developed by Lyublinskaya and Tournaki (2011) and the discussion on PSTs' interpretations to implementing technology based mathematics lessons. In addition, this chapter of the dissertation included implications, and recommendations.

#### **5.1 Discussion on Changes in PSTs' TPACK through the Study**

The first overarching goal of this qualitative case study was to determine PSTs TPACK levels in different teaching experiences and investigate the changes and adaptations in PST's TPACK through the study. To reach this goal three main component of the lesson: the aim of the lesson, the questions used, and the role of the teacher was investigated to determine the change in the TPACK level of the PSTs.

First common theme that emerges from the analysis is the change in the aim of the activities. As PSTs gained experience in a genuine classroom context, the aim of the technology-based activity was changed. For example, in the first lesson the case Meltem used GeoGebra software to demonstrate a dynamic model for a real life problem and gave students hints about how to solve the problem. The technology-based activity

assisted Meltem in helping her students to work out the solution to the problem. However, in the first lesson only a very limited number of students got the chance to use the educational technology to explore.

In the second lesson Meltem used GeoGebra software to model another real life problem. This time she constructed two trial activities using GeoGebra with the aim of having the students explore and predict the exact place for a flag in a triangular field by themselves. These trial files enabled the students to notice the location of the circumcenter of a triangle. In the third lesson the purpose of the three activities was parallel to the second lesson. In this lesson the students observed the relationship between geometrical concepts and commented on them. In the first activity, dynamic visualization of ratio between the central angle and an inscribed angle helped students notice that the ratio between them is always constant. Similarly, the aim of the third activity was to have students notice the relationship between the angle of rotation and the distance traveled depending on the starting point of the box. Visualization of the pulley relative to the central angle and its arc helped students understand the logic behind the pulley system. In the last activity the students were given clues and challenged to find a center point that was equidistance from three points. A change in the aim of the technology-based activities was observed in the activities of case Pelin as well. In her first implementation Pelin's reason for using educational technology was drill and practice. She used the spreadsheet program to generate addends and subtrahends in the standard algorithms. In the activity the students calculated the results of operational computations procedurally. In the second lesson the students discovered triangle inequality and angle/side relationship in a triangle through explorations. In parallel with the second lesson, the purpose of the third lesson activity was to have students discover the geometric representation of algebraic identities. Pelin used a geometric model of  $(a-b)^2$  and  $a^2 - b^2$  identity to visualize the algebraic identities. The third case was Ali. For the first lesson Ali constructed a geometrical model of Pythagorean Theorem using GeoGebra software. This activity helped students visualize

the relationship between the sides in a right-angled triangle. However, it did not offer real proof for the Pythagorean Theorem. In the second lesson Ali constructed a dynamic model for decimal numbers using the GeoGebra program. The GeoGebra activity incorporated a dynamic environment to construct geometrical models of different decimal numbers between 0 and 1. In the third lesson Ali used the dynamic nature of the GeoGebra program to have students observe the geometrical model of the  $2x^2 + 5x + 2$  quadratic expression. While in the first implementations educational technology was mostly used for students' procedural exercises, in the second and especially in the third implementation educational technology was used to have students explore a mathematical concept. These findings demonstrate that PSTs altered the aim of the lessons in classroom teaching. Instead of using technology for drill and practice, PSTs used educational technology to support students' conceptual understanding by visualizing and discovering relationships. In a parallel study Mudzimiri (2012) also found that the participants' initial conceptions were that technology is used for drill-and-practice. In the designing and implementing the second group lesson the participants appeared to have progressed in their TPACK. In this study, the participants initially focused on how to use the technology in their first lesson implementation rather than how to explore mathematical concepts via technology. This showed a lack of awareness of the strategies and representations for teaching mathematics with technology. In their second group lesson implementation, they showed progress in terms of focusing more on mathematics than technology in order to have students explore mathematical concepts using educational technology (Mudziri, 2012). Mouza and Wong (2009) also stated that teachers learn from experience in their TPACK-based case development strategy. By implementing technology-based lessons PSTs get the chance to see concrete examples of how dynamic geometry software can be used effectively in a mathematics classroom thus driving students to discover, explore or comprehend a concept (or a set of concepts) and directing them towards a deeper level of understanding of these concepts.

The second common theme that emerged from the analysis was the change in the type of questions. As PSTs gained experience in real classroom context, in parallel with the change in the aim of the technology-based activities the type of questions also changed. For example, in the first lesson the questions that Meltem asked gave hints to enable the students to notice the solution to the problem. Using hints Meltem had tried to engage students in the solution process of the problem. However, the questions were so difficult that very few of the students were able to answer. In addition, she didn't give enough waiting time 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 GeoGebra software. She allowed students to present, pose their ideas, interpret, compare, and reflect on the solution of the problem. She gave more effort to engage the students in the class discussions by asking reasonable questions. In the third lesson, in parallel with the second lesson, Meltem continued to display a more constructivist form of pedagogy and gave her students the chance to experience mathematical discoveries via GeoGebra software. Meltem did give enough waiting time for her students to explain their answers in the second and third implementations when compared with the first implementation. A change in the lesson's questions was observed in the case of Pelin as well. While in the first implementation Pelin's questions required students to carry out drill and practice relating to addends and subtrahends in standard algorithms, in the second and third lesson implementations the questions required the students to reason through mathematical concepts and their relationships. In the first lesson the students did not use technology to explore mathematical ideas. The technology-based activity was not planned in such a way as to explicitly promote student knowledge by posing questions so that they could make sense of the lesson. Therefore, there were no questions requiring the students to reason through the definition of decimal numbers. In the second lesson, using educational technology, students made judgments related to triangle inequality and angle/side relationships through checks and critiques. Pelin asked her students questions to enhance their

investigations. The students explored mathematical relationships and confirmed their reasoning. In the third lesson Pelin asked questions using a technology-based activity and encouraged students to conjecture about the geometrical model of identities. The technology-based activity provided an environment to facilitate students' reasoning on the geometrical model of identities. There was a change in Ali's questions as well. In the first lesson, the questions that Ali asked required students to use Pythagorean formula to find the missing sides in a right-angled triangle. There were no experimental activities using GeoGebra to help students discover the relationship between the lengths of the sides in a right-angled triangle. Ali did not ask any challenging questions in the first lesson that would promote student knowledge. In the second lesson, Ali asked questions to have the students compare two decimal numbers based on their models. His goal was to have students construct meaning from the geometrical models about decimal numbers. In the third lesson, Ali put questions to the students to help them analyze the geometrical model of algebraic expressions. The students observed the activity and answered the questions that Ali posed. The GeoGebra program provided students with a visual environment to compare the models that they had constructed with a physical medium. Zbiek (2003) also emphasized the importance of classroom discussions to facilitate the emergence of mathematical ideas through rationalizing mathematical concepts in technology-based lessons. Therefore, it is important to create discussion environments for pedagogical dialogue related to instructional procedures concerning how to use technology in mathematics lessons. For example, PSTs first underwent technological training and then they examined the activities by discussing how and when to use the appropriate technology in mathematics instruction. The ELE 430 course experience might have supported the observed change in PSTs teaching. To participate in this study, the primary criterion was enrolment in the ELE 430 course in order to select participants familiar with the educational technology. In the ELE 430 course the instructor provided examples of those GeoGebra activities that serve students' conceptual understanding. The instructor encouraged PSTs to prepare student-centered

activities to engage students in the mathematics lesson using educational technology. Then instructor guided PSTs to create discussion environments on pedagogical dialogue related to instructional procedures concerning how to use technology in mathematics lesson. Discussing these issues in the ELE 430 course might have contributed to PSTs' TPACK in terms of asking questions with the help of educational technology while the students were exploring the technology-based task. The technology-based activities prepared by PSTs for this study led students to engage in classroom discussions. Using questions PSTs helped students to explain their reasoning and compare their solutions with others etc.

The third common theme that emerges from the analysis was the change in the role of the teacher. As PSTs gained experience in a genuine classroom context, the change made to the aim and the questions in the lessons altered the PSTs role in the technology-based lesson. For example, the role of Meltem in the first lesson was lecturer. In the first lesson Meltem used a teacher direct approach and used technology to assist her teaching. Technology was rarely used by students since design of the lesson did not support student's independent use of technology for exploration. In the second lesson Meltem prepared a dynamic environment for students to explore the location of the circumcenter of a triangle. She observed students' experience in the groups and gave feedback to them. She promoted student reasoning by posing questions that got them to make sense of the relationships between geometrical concepts. Meltem served as a guide for student learning using technology in the computer lab. In the third lesson, in parallel with the second lesson, Meltem used educational technology to have her students make judgments about geometrical rules. The activities she constructed offered opportunities for "math talk" to take place between students and other students, and between students and teacher. In this lesson Meltem's role was that of guide to promote students' reactions and make sense of mathematical concepts using GeoGebra. The change in the role of the PSTs was observed in the case of Pelin as well. Pelin's first lesson was a teacher-directed lesson. In the first implementation Pelin's role was that of lecturer while in the



second and third lesson implementations Pelin served as a guide for student learning. The first lesson was a teacher-directed lesson. During the lesson Pelin used a spreadsheet to demonstrate standard algorithms. In the second lesson Pelin considered drawbacks of the first lesson and she used technology to develop students' conceptual understanding of a mathematical concepts. In the second lesson Pelin's general approach was student center. Educational technology provided an environment for students to do mathematics with discoveries, and Pelin served as a guide of student learning with technology. In the third lesson the role of Pelin was that of a guide and she posed questions to have students make sense of mathematical concepts associated with GeoGebra representations. In the third lesson Pelin's role was again that of a guide. She asked questions to challenge students to model  $(a-b)^2$  and  $a^2-b^2$  identities. There was a change in Ali's role as well. In his first lesson Ali's role was that of a lecturer. The questions he asked did not challenge the students to think about the model. The students in the Ali's first lesson did not use technology to explore the mathematical concepts. Ali's role in the first lesson was that of a lecturer. While students used technology to observe the relationship between the sides in a right-angled triangle, Ali used teacher led instructional strategy to have students make judgments about this relationship. However, he didn't ask challenging questions to have students think about the model. Nevertheless, after his lesson he recognized the drawbacks of his approach and attempted to improve his teaching skills in the second lesson. In this lesson Ali used teacher led instructional strategy to have students make judgments about the decimal numbers. He asked questions that helped the students to find geometric meaning in decimal numbers. In the second lesson Ali's role was that of a guide to support student investigations involving models for decimal numbers. He took care to ask questions that would have students reasoning about the geometrical model of decimal numbers. In the third lesson Ali's role was that of a guide to promote students' reactions and to help them make sense of mathematical concepts using GeoGebra. In his last lesson he used physical media to support his technology-based activity. He asked students to compare

their models with the models in the GeoGebra file. This created a discussion environment and gave students the chance to share the similarities and differences between their models for  $2x^2 + 5x + 2$  quadratic expression. The students observed the activity and answered the questions. The students saw that they can switch between the parts of the model and it will still represent the same quadratic expression. Using physical media in technology-based lessons helps students construct their own understanding by modifying and changing the pieces. The role of teachers in the second and especially in the third technology-based lesson was that of a guide. Zbiek (2003) stated that the use of technology in mathematics instruction helps teachers to foster students' mathematical thinking (Zbiek, 2003). Technology is an effective tool for guiding students through the reasoning process.

The evidence in three cases showed that through the implementation of three technology-based lessons in a genuine classroom context PSTs made changes to their technology based teaching and TPACK levels over the course of the three lessons in accordance with the TPACK levels rubric developed by Lyublinskaya and Tournaki (2011). The aim of the technology-based activity is an important factor in determining the role of the teacher and the type of the questions that the teacher needs to ask in a technology based lesson. If the aim of the activity supports students' individual explorations the teacher should ask questions that have students reason through mathematical concepts and develop their conceptual understanding. The role of the teacher in the exploration of mathematical concepts is most likely to be that of a guide. Hixon and So (2009), stated in their study that technology-based lesson implementations are critically important in developing PSTs' TPACK since the construction of technology-based activity and its implementation in a genuine classroom context give PSTs a chance to pilot their ability. Upon the completion of this study PSTs gained experience in technology-based teaching, which in turn contributed to the development of their TPACK. Valanides and Angeli (2008) also found that as teachers gain more experience they feel more competent in integrating technology in their classrooms in a

student-oriented fashion. Moreover, Zeincher (2012) claimed that teaching experience helps PSTs develop the professional vision and skills for this process. Limited classroom experience influences the extent to which PSTs can design effective technology-integrated instruction (Mouza & Karchmer-Klein, 2013). In parallel with the literature PSTs developed vision about the aim of the technology, the importance of the questions and the role of the teacher in a technology-based classroom. The change in TPACK level was directly related to the aim of the lesson, the questions used, and the role of the teacher.

In the present study, in addition to field experience the contribution of reflection-on-practice in developing PSTs' TPACK was also emphasized. The reflection-on-action process might have contributed to the shift in PSTs' technology-based activities over the course of the implementations. Before the lesson PSTs presented their technology-based activity and explained how they would use the activities in the teaching experience. Then the researcher provided feedback. Based on these feedbacks PSTs revised the activities and lesson plans. After the lesson PSTs reflected on the lesson implementation they had experienced. Specifically, PSTs' performance in using educational technology in teaching was criticized by themselves with respect to the purpose of the activity (cognitively challenging), the role of the teacher (a guide and help students focus on reasoning), and role of the questions (to guide students into exploring mathematical concepts, discovering relationships between mathematical concepts). In the first implementations the PSTs' lesson plans were inadequate as were their implementations in terms of aim of the activity, the questions asked and the role of the teacher. In their interviews the PSTs were asked to give a brief summary of the lesson implementation and to air their thoughts about their performance with specific explanation of the important points. If PSTs had any problems while implementing these activities, they discussed them in the reflection-on-practice process, as well. In order to develop a clearer understanding of PSTs' opinions about educational technology, the researcher's questions and recommendations for the next implementation were discussed during

interviews. The aim here was to obtain information about how pre-service teachers come to understand the use of dynamic geometry for teaching mathematics, for reasoning, and for communicating significant mathematical points, as well. Reflection-on-practice gives PSTs the opportunity to reflect on these issues. This process helped pre-service teachers bring together different knowledge bases in order to design and implement effective technology-integrated lessons. As they repeated classroom experiences using technology and reflection processes they compensated for these deficiencies and improved their technology-based teaching skills. The result of Mouza and Karchmer-Klein study (2013) indicated that designing, enacting and reflecting on technology integrated classroom experiences enables pre-service teachers to recognize connections between technology, content and pedagogy, and to advance their TPACK. In that respect, the combination of the field experience and reflections on action might be helpful in improving PSTs' TPACK in this study. In a parallel study Mouza and Karchmer-Klein (2013) stated that in the process of analyzing and reflecting on their own practice in technology-integrated classroom experiences, participants reconsidered the role of technology in supporting student-learning processes. In the present study as PSTs gain experience their opinions on the role of technology in supporting student-learning processes changed in parallel with the aim of the technology. They used educational technology to support student conceptual learning.

Niess (2011) emphasized the importance of the reflection processes on PSTs' understandings and thinking about teaching using educational technologies. The reflection-on-action process drove PSTs to analyze their own practice, which in turn contributed to changes in their teaching and in student learning. Reflection-on-action was implemented in this study in order to challenge PSTs about their teaching experience. Accordingly, PSTs were interviewed before and after each lesson implementation. Before the lesson, lesson plans were examined and necessary revisions were made together. PSTs explained how they were going to use technology-based activity to facilitate students' understanding. After the lesson PSTs criticized their lesson

implementations with respect to whether or not technology usage was consistent with subject matter teaching. In a parallel study Mouza and Karchmer-Klein (2013) stated that in the process of analyzing and reflecting on technology-integrated classroom experiences from their own practice, participants identified important aspects of the technology-based lessons. This process of turning the experience into a narrative triggered the kind of reflection help participants make insightful shifts in their thinking about technology. In parallel with this result, the present study supported the shift in PSTs thinking about technology in this process. Interviews relating to each lesson implementation were conducted in order to gain information about PSTs opinions. For example, Meltem stated in the first interview that using technology gave students the chance to observe the motion dynamically and for them to make a good enough interpretation about the area of triangles to solve the problem. In the second interview she noticed the importance of the questions and this time she stated that she used educational technology to have students explore the motion dynamically and to make interpretations about the relationship between geometric concepts by themselves. She reported in the third interview that technology needed to be integrated into mathematics in order to get students to explore geometrical concepts and to challenge them with questions in order to support their reasoning using educational technology. Although Meltem was already experienced in terms of using technology in mathematics education according to the TPACK levels rubric at the beginning of the study, a shift in her thinking was seen while integrating educational technology in mathematics teaching. This shift was clearer in the case of Pelin. In the first post-lesson interview she stated that the use of technology in the first lesson was not very essential since it was also possible to display the computational results by writing on the board. In addition, she criticized herself for not asking challenging questions in a way that supports students' conceptual understanding. In the second lesson she stated that she used educational technology to have students make experiments to discover triangle inequality and angle/side relationships by themselves. She stated in the interview that this time

educational technology assisted her in asking questions and helping students discover relationships between mathematical concepts. Students tested conjectures using educational technology and she asked questions that got her students to explain their opinions about these relationships. In the third implementation she stated that she used educational technology to model algebraic identities. Dynamic models provided students observe the geometric construction of identities. She stated that educational technology supported students in discovering the geometric meaning of algebraic identities. She stated in the last interview that technology-based teaching experience had contributed to her knowledge the effective use of educational technology in teaching mathematics. She believes that there was an improvement in her performance over the course of the three lessons. A shift appeared in the case of Ali, too. For the first lesson he constructed an activity to demonstrate Pythagorean Theorem dynamically. He stated in the interview that this activity helped students to recognize the relationship between the edges of a right-angled triangle. However, since he had not prepared a real proof for theorem, the students did not recognize the proof of Pythagorean Theorem. In addition, he criticized himself for not asking challenging questions to the students in order to create a discussion environment. For the second lesson he constructed a dynamic model for decimal numbers. The students were able to visualize the dynamic model of the decimal numbers and made a comparison between their magnitudes. In the second post-lesson interview he stated that this time educational technology allowed the students to discover the geometrical representation of decimal numbers. However, Ali stated that he was unable to create a discussion environment in the classroom again since the students had already learned decimal numbers previously. For the third lesson, Ali constructed a dynamic model of a quadratic equation. In the third post-lesson interview he reported that he used educational technology to visualize the model of a quadratic equation. In this lesson the students observed the dynamic model of a quadratic equation and discovered its geometrical representation. In Ali's opinion, technology is a practical tool for teaching mathematics. He reported that after having this experience he improved his

techno-pedagogical skills and was ready to teach mathematics using technology. He improved his ability to use educational technology in teaching effectively after taking technology-based courses. He also wants to learn new programs and has improved his proficiency with GeoGebra.

Mouza and Karchmer-Klein (2013) stated in their study that the process of analyzing and reflecting on technology-integrated classroom experiences from their own practice enabled participants to make plans for the future. In parallel with this result the participants of this study had plans for future technology-based lessons. PSTs shared their ideas as a teacher as to whether or how these implementations were likely to influence their future practice. For example, Meltem reported that she felt like a genuine teacher in this process and noticed the difficulties of using technological materials in the lesson to teach a subject to students who had never used any materials in their lessons. Gaining experience via educational technology in the classroom also helped her to see her own deficiencies in terms of technical knowledge and techno-pedagogical content knowledge. She evaluated her progress and said that one of her assignments for the ELE 435 course had given her the most educational experience for her as a future teacher. She considered herself ready for future technology-based teaching. Pelin also considered the drawbacks of her lessons and planned to design more professional technology based lessons for her future teaching. However, she did not feel ready to teach mathematics using technology since she needs more technology-based courses to improve her own technical skills and teaching methods first. In addition, she has some concerns about the use of educational technology in our education system in the future since its infrastructure is not ready to use. According to her observations in collaborative schools, teachers never use educational technology in their teaching. Students have not heard of dynamic geometry programs. She expects her future school to employ technological equipment and to have both teachers and students conversant in technology in order to be able to carry out technology based lessons. For the same assignments for the ELE 435 course Pelin also defined this process as the most educational experience for her

future career as a teacher. Ali also stated that after having this experience he improved his techno-pedagogical skills and was ready to teach mathematics using technology in future lessons. In addition, on the one hand he believes that teachers should learn how to use educational technology specific to their teaching area, on the other hand he believes that teachers do not need to use educational technology to teach every single mathematics subject, since some subjects are better taught using physical media i.e. place value can be taught using ten blocks. In his opinion, using technology in teaching also brings some technical problems with it. Teachers should have the necessary knowledge to eliminate these problems otherwise it turns into a waste of time. As an assignment on the ELE 435 course Ali wrote a self-improvement paper. In this paper he stated that learning how to use dynamic geometry programs was beneficial for his professional experience as a teacher. Even if he was not an expert user of GeoGebra he was nevertheless able to create the basic activities that he need in his lessons. The technology-based lesson implementations in field experience had improved his skills in using educational technology in his teaching. He is planning to use this program in his teaching when he becomes a math teacher next year.

Another common theme that emerges from each interview was the PSTs' increase in self-confidence. PSTs stated that in the implementation process of this study they became more confident in their ability to teach mathematics using technology. PSTs also indicated in the interviews that these implementations raised their awareness about their TPACK in practice and contributed to their self-confidence in using educational technology in their teaching. Ali in the second lesson stated that he felt much more enthusiastic when compared to his previous implementation. He was getting used to using technology in his teaching.

In order to use educational technology effectively in mathematics teaching each component of TPACK is important. To integrate educational technology in mathematics teaching PSTs needed to have CK (the various mathematics contents in the curriculum, the relationships between them and content-specific instructions) and TK (technical



skills to construct lessons using educational technology) to design a technology-based teaching activity. In order to implement this lesson PSTs also need to have PCK, and to use technology in teaching process PSTs need to have both TPK and TCK. The effective technology based lesson requires teachers to have all these knowledge fields together. TPACK develops after the implementation of several technology-based lessons. Therefore, to develop their TPACK PST should gain experience in a classroom context as a teacher. This process enables PSTs to acquire TPACK progressively in their professional practice in parallel with the studies conducted by Niess et al. (2007) and Mouza and Karchmer-Klein (2013).

In conclusion, the present study mainly suggests the restructuring of the field experience so as to maximize the opportunities for PSTs' TPACK development. Using these implementations it is aimed to give PSTs a chance to construct, observe and teach mathematical concepts and challenges, and improve their TPACK in mathematics.

## **5.2 Discussion on Noticed Issues with respect to PSTs' Interpretations Regarding Their Experiences with Educational Technology**

The third overarching goal of this study is PSTs' interpretations regarding experience of technology-based teaching activities using educational technology over the three lessons implementations in the field. During this process PSTs commented on the role of educational technology in mathematics teaching. This part of the study discusses PST's comments about their experiences with educational technology through lesson implementations and reflection-on-action processes.

The thirteen themes that emerged in the final interview were classified into three categories. The categories and their themes were: lesson preparation (students' pre-knowledge, lesson objective, location, necessity of the technology, motivation), process of implementation (tools, teacher's role, activity sheet, classroom management, time

management, implementation), and mentorship (having a facilitator, and recommendation).

The first category lesson preparation includes students' pre-knowledge, lesson objective, location, necessity of the technology and motivation. In PSTs opinion, when designing technology-based mathematics lesson the first component that needs to be considered by teacher is students' prior knowledge. PSTs reported that before designing a technology-based lesson, teachers should be aware of their students' prior knowledge about mathematical concepts and their familiarity with educational technology. During the study PSTs in some cases experienced that students with insufficient prior knowledge were unable to participate in class discussion. Also, some students answered all the questions without reasoning since they already knew the subject. Similarly, when students were not familiar with the use of educational technology this caused time consumption since students needed extra time to learn how to use technology in the lesson. In a parallel study conducted by Mouza and Karchmer-Klein (2013) it was found that in many cases PSTs overestimated their students' technological competence and were surprised to see that their students lacked the fundamental skills to use educational technology. Looking back at their experience, PSTs noted that in the future they would need to determine students' prior knowledge at the beginning and then design a technology-based lesson accordingly.

The second theme that PSTs considered when designing a technology-based lesson was lesson objective. In PSTs opinion, educational technology is just a tool to have students reach the lesson objective, and not the main component of a technology-based lesson. Teacher focus should be on using educational technology effectively to have students reach the lesson objective. During the study PSTs experienced in some cases that students focused more on technology than actually learning the mathematical concepts being taught in the lesson.

The findings of the study implicated that the location of the technology-based lesson needs to be consistent with the aim of the technology-based activity. For example, if

the technological activity requires students to observe and discuss, the lesson might be better implemented in classroom environment. However, if the technological activity requires students to construct a mathematics concept, create a model, explore and discover a mathematical relationship, it would be more appropriate to hold the lesson in the computer lab in order to use educational technology effectively since that is the best place for using a dynamic geometry program for dragging objects, tracing points, changing parameters and measuring objects etc. During the study, PSTs experienced in some cases that the computer lab might be more appropriate for students to explore mathematics concepts individually. In the classroom class time is dominated by the teacher using educational technology to teach; while, in the computer lab the students use educational technology by themselves to learn. However, the computer lab is not always necessary when the teacher wants to have students explore and discover a mathematical relationship if the students each have their own tablet PC in class. The computer labs used in this study were traditional. i.e. they had fixed seating and were not well suited to class discussion. In Turkey the government aims to provide each and every student with a tablet PC to with the FATİH [Movement for Increasing Opportunities and Improving Technology] Project (Karal et. al, 2013).

Fourthly, the necessity of the technology when teaching a mathematical concept is another issue that PSTs commented on in the interviews. PSTs stated that using educational technology in teaching overloads a teacher's workload since it saddles the teacher with additional responsibility. Firstly, the teacher needs to construct technology-based activity using his/her own technical skills or to obtain this activity from educational sources, and then design the implementation of the lesson in detail. In addition, teachers have to prepare the classroom environment to be compatible with the technological activity. Furthermore, he/she needs to have a back-up plan in case of any unexpected situation. Therefore, PSTs stated that teachers only incorporate educational technology in teaching when it is essential to teach a mathematical concept. For example, to make abstract concepts concrete, to represent a three-dimensional object, to

display how different parameter values change the graph of a function, to model a real life problem, to justify students' solutions, to explore the relationship between two mathematical concepts and to discover the relationship etc.

The final issue that PSTs commented on with respect to the lesson preparation category was the potential of educational technology in motivating students to learn mathematics. PSTs claimed that students were eager to learn mathematics when they used educational technology since students need to explore or observe the mathematical activity using technology. Students also confirmed this claim in their self-assessment papers. At the end of the lesson they reported that technology motivated them to learn. Teachers can use educational technology to motivate students into learning. Mouza and Karchmer-Klein (2013) found that interactive learning with technology gives students a fun and interesting way of learning new concepts. The participants of this study came to realize that interactive online resources can be more engaging and effective than lecturing because they can help students visualize complex concepts while holding their attention for a longer period of time in the lesson.

The second category was process of implementation which includes tools, teacher role, activity sheet, classroom management, time management and the classroom implementation experience themes. A first common theme that emerges from the analysis of the interviews was that PSTs perceived educational technology as a tool to extend mathematics teaching and promote students' learning. In the present study PSTs used GeoGebra specifically to help visualize mathematical concepts. PSTs reported that visualization of mathematical concepts using dynamic geometry software helps students make abstract mathematical concepts concrete. The National Science Foundation (1987) also asserted that visualization of mathematics concepts transforms the symbolic into the geometric form and enable students to observe their simulations and computations. Visualization enriches the process of scientific discovery and fosters profound and unexpected insights. In a parallel study Agyei (2013) explored the potential of spreadsheet programs as an instructional tool to impact PSTs' instructional practices and

students' learning. In that study the spreadsheet program was merely a tool to facilitate the students' gaining of mathematical understanding. PSTs recognized the advantages of using an interactive spreadsheet program to explore and expand their knowledge of instructional strategies for integrating spreadsheet-learning activities and enhancing students learning. Otherwise, there are times when it is not urgently necessary to use educational technology in teaching.

The second theme in the process of implementation category was teacher role. In parallel with the researcher's observations, PSTs described the role of teacher in technology-based classroom as a guide. They commented that teachers needed to utilize teaching methods that require students' individual exploration of mathematical concepts and active participation in class discussion in order to integrate technology in instruction. During the study PSTs in some instances found that when they encouraged students to take responsibility for their own learning via technology the students were more enthusiastic in the lesson. Looking back at their experience PSTs noted that in the future their role in a technology-based classroom might be as a guide to help students construct their own understanding.

The third theme that PSTs commented on in the interview relating to the process of implementation category was the necessity of the activity sheet in technology-based classrooms. PSTs prepared activity sheets to provide instructions about the various steps of the technology-based activity. The activity sheet included questions inquiring as to the students' opinion on certain statements in the discussion process. In addition to have students' exercise related to topic of the lesson the activity sheet included drill and practice. During the study PSTs sometimes found that when PSTs prepared an activity sheet it served as a guideline throughout the technology-based activities. With the help of the activity sheet students were able to follow the technological activity and carry out what they were supposed to be doing. The clues about the next step of the activity kept students alert within the lesson. In their study Mouza and Karchmer-Klein (2013) stated that handouts having clear directions for students as would keep students focused on the

topic and allowed for a more accurate estimation of the time required to complete technology-integrated activities.

The fourth theme that PSTs commented on in the interview relating to the process of implementation category was classroom management. PSTs stated that in technology-based classrooms since teachers need to oversee the usage of educational technology there might be harder to maintain authority over the students. In the lab environment in particular, following each student individually at the same time makes classroom management harder when compared with traditional classrooms. During the study PSTs found in some cases that there was a classroom management problem stemming from the use of educational technology.

Time management is the fifth theme that PSTs commented on in the interview relating to the process of implementation category. PSTs found that educational technology saves time only when there are no technical problems. However, when a technical problem did occur PSTs lost time fixing the problem and had very little time left to complete the rest of the lesson. PSTs recommended that teachers need to have a back-up plan in case of any technical problems. During the study PSTs sometimes found that there were time management problems stemming from technical problems related to technology-based activity. In their study Mouza and Karchmer-Klein (2013) stated that in the event of technological problems teachers need to have back-up plans to keep students focused on the task when operating the computers.

The final theme that PSTs commented on in the interview related to process of implementation category was the classroom implementation experience. PSTs stated that experience in technology-based lesson implementation contributed to their future teaching. PSTs reported that this experience enabled them to see their strengths and weaknesses in terms of using educational technology in teaching. Moreover, the more technology-based lessons they carried out the better they were at being able to interpret the students' reactions to the lesson and predict the kinds of questions they would ask in

relation to the task. They felt more comfortable in the classroom as a teacher in their third lesson implementation.

The third category - mentorship - involves having a facilitator and recommendation themes. Having a facilitator in this implementation process was the first theme related to this category. PSTs appreciated being observed during the lesson implementation and having an interview before and after each lesson implementation to reflect on the quality of their teaching. PSTs claimed that the reflection-on-action process challenged them to reconsider their instructional practices and gain a clearer understanding of their own individual teaching styles. Discussing the positive and problematic sides of the lesson and receiving feedback helped them work on their weaknesses for the next lesson. The study conducted by Gaiimo-Ballard and Hyatt (2012) claimed that the practice of self-assessment in reflection helps teachers to improve their teaching skills.

The second theme in the mentorship category was recommendation. Based on their experiences in the present study, PSTs offered some suggestions to teacher educators related to developing PSTs' techno-pedagogical knowledge at the end of the study. PSTs suggested that teacher-training programs should include compulsory courses concerning the usage of content-specific educational technology courses such as ELE 430, which they had enrolled in before the current study. In addition, method courses should be extended with educational technologies for each specific mathematics context. In this course the available educational technologies should be introduced to PSTs and example activities should be conducted that match with mathematics content, educational technology and teaching method. PSTs recommended technology-based field experience to improve TPACK. PSTs claimed that then they combined their content and pedagogical knowledge with technology their awareness about their TPACK was enhanced. As they engaged in the classroom environment with educational technology they could see their strengths and weaknesses relating to their TPACK as a teacher. PSTs stated that as the number of lessons increased they were better able to predict

possible problems they might encounter in the lesson and even students' reactions to the lesson. In addition to this, PSTs recommended writing reflection papers about their teaching practices in the field in order to review this process and share their experiences with each other.

### **5.3 Implications of the Study for Educational Practices**

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. Pre-service teachers, as future teachers, ideally should be able to use educational technologies in teaching effectively. Therefore it is important to increase teacher candidates' awareness about the potential of educational technology in mathematics teaching. The present study underlines the field experience supported with reflection-on-practice processes in order to enhance PSTs' TPACK for teaching mathematics. In the content of this study PSTs were challenged to combine their content knowledge, pedagogical knowledge and technological knowledge to design technology-based mathematics lessons and implement them in the context of real classroom environment. PSTs were expected to develop a perspective in teaching and learning of mathematics through the use of educational technology in real classroom settings. PSTs interacted with educational technologies and constructed specific ideas about how to use technology in their teaching effectively. During this experience PSTs identified different features of educational technology and the potential for integrating technology in the mathematics curriculum. Implementing and reflecting on their technology-integrated lessons, the participants gained important insights on the value of the aim of technology-based activity, the type of questions that they need to ask and their role in technology-based mathematics lessons.

In reflection-on-practice process, important interpretations of the PSTs related to educational technology were tool use, role of the teacher and technical considerations. In



the implementation of technology-based lessons PSTs' experienced how technologies could be used to foster students' mathematical thinking and how technology could help them address the problems that students face. In this process PSTs noticed that educational technology alone does not improve student achievement. Educational technology is a tool to extend mathematics teaching and promote students' learning. In addition, PSTs noticed the potential of the technology to motivate students to learn mathematics. Another important interpretation of the PSTs was the role of the teacher in technology-based classroom. PSTs stated that the role of teacher in technology-based lesson was a guide. In the lesson teachers give students the chance to develop their self-learning using educational technology. While doing this students' prior knowledge about mathematical concepts as well as their familiarity with educational technology should also be considered by teacher. In addition, PSTs recommended that teachers need to have a backup plan in case of any technical problems to save time in technology-based classrooms. Those were the important points that PSTs teachers suggest teachers when deciding how best to use educational technology in their teaching.

This study claimed that technology-based lesson implementations coupled with reflection-on-practice helped support PSTs' TPACK development in field experience. 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 PSTs' TPACK increased. At least three technology-based lesson implementations are suggested to determine the PSTs' TPACK level. This process might give clues to teacher educators about how to design field experience courses that will help pre-service teachers deal with technology-based teaching activities.

#### **5.4 Recommendations for Further Research**

Today's students are digital natives and they are able to use technology in every aspect of their life. PSTs are entering a teaching field that requires them to use technology professionally. Therefore, mathematics teachers need to learn how to use specific technologies in their teaching before they graduate. This study investigated the contribution of field experience and the reflection-on-practice process to PSTs' TPACK. The participants of the study were able to design technology-based lessons at the beginning of the study, but there was an experience gap in their application of knowledge when putting theory into practice. In order to cover this gap PSTs implemented content-specific educational technology applications in a real classroom setting and reflected on their teaching practices.

In this process university facilitators and mentor teachers played an important role in helping PSTs to bridge theory and practice. Ideally, university facilitator assist PSTs in the reflection-on-action process and mentor teachers should have been a role model for PSTs when carrying out technology-based lessons. However, in the current study since mentor teachers did not use educational technology in their teaching, they were unable to be role models for PSTs in a technology-based classroom context. This being the case, there is a need for programs that train mentor teachers and facilitators in order to fulfill their profession. To this end, teacher educators can design content-specific technology-based professional development programs for mentor teachers as well as seminars and workshops for university facilitators to improve their skills in the reflection-on-action process, which takes place in both school and university contexts. These training programs might enable mentor teachers and facilitators to become more professional as guide for PSTs in their TPACK development process. In-service teachers should have the technical skills and pedagogical content knowledge to provide PSTs concrete examples for effective usage of educational technology in mathematics teaching. University facilitators also gained experience in these seminars and workshops

in having PSTs reflect on their teaching performances in terms of development of TPACK. For further research it would be useful to conduct a research study to examine the role of facilitators and mentor teachers in the context of field experience courses and to explore how they can collaborate with each other in order to contribute to PSTs' TPACK and share information regarding their progress. It is recommended that teacher educators consider these issues when designing field experience courses to enhance PSTs' TPACK. In these studies researchers need to clarify the kind of content-specific technologies that they used (dynamic geometry, graphic calculator, spreadsheets etc.) and detail the instructional interventions and guidelines for specific lesson designs that they provide to teachers to improve their TPACK. The researchers then need to evaluate the potential of their intervention for extending PSTs' TPACK.

In addition, a similar study can be conducted with in-service teachers to compare pre-service and in-service teachers to determine whether or not experience creates a difference between them in terms of TPACK development. In-service teachers' comments on technology-based mathematics lesson might also contribute to TPACK literature. Furthermore, it might be useful to conduct a longitudinal study with pre-service teachers starting from their pre-service training through to a certain period of their in-service teaching to investigate how their TPACK and their comments about this process change over time.

Due to the lack of a clear definition of technology integration as well as the vagueness of the criteria used to assess the quality of technology-based lessons there is need for studies to frame this issue. Integration of technology-based courses in teacher education programs to develop PSTs' TPACK is urgently needed in the field of teacher education. New studies are needed to extend the present study and identify other ways of preparing teachers to integrate technology in their teaching effectively.

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## APPENDICES

### APPENDIX A

#### SYLLABI

##### A.1 Syllabus of ELE 430 Course

Exploring Geometry with Dynamic Geometry Applications

Spring, 2011

Monday 13.40-15.30 (EF 24) & Thursday 10.40-12.30 (EF 24)

##### **Instructor**

*Dr. Didem Akyüz*

e-mail: dakyuz@metu.edu.tr

##### **Assistant**

Elementary Mathematics Education

Arş. Gör. Aykut Bulut

Office: EF37 - 7508

e-mail: abulut@metu.edu.tr

##### **Goals**

The purpose of this course is to help you study and gain variety of perspectives in teaching and learning of geometry and mathematics through the use of Geogebra. ELE 430 aims to develop an understanding of the main issues in elementary mathematics education in order to support an understanding of the important concepts, principles, approaches and theories of teaching and learning mathematics and geometry in classroom settings. Upon the completion of this course, I expect that students

- Construct objects, figures, and diagrams; explore their mathematical properties.
- Generate teaching aids, including worksheets, tests, reports, and presentation materials.

- Create simulations that make use of dragging, animation, tracing loci, and random point generation
- Make conjectures and test hypotheses about Euclidean geometry.
- Analyze and solve various geometric and/or trigonometric problems.
- Create Escher-like tessellations and tilings of the plane.

### **Required Materials**

King J., & Schattschneider, D. (Eds.) (1997). Geometry Turned On: Dynamic Software in Learning, Teaching, and Research. The Mathematical Association of America

Geogebra website <http://www.geogebra.org>

InterMath, from University of Georgia <http://intermath.coe.uga.edu/>

### **Grading**

|               |     |
|---------------|-----|
| Projects      | 40% |
| Write-ups     | 25% |
| Assignments   | 20% |
| Portfolio     | 10% |
| Participation | 5%  |

Details of the assignments will be announced in the class.

### **Attendance and Participation**

You are expected to demonstrate energetic, high quality performance in all aspects of this course. Regular attendance is expected and required in the laboratory sessions. Your attendance and participation in classes will be reflected in your grades.

**Late Assignments**

I expect that assignments will be turned in by the announced due dates. I will accept assignments after the due date, but your grade will decrease by 10% of the allocated points for each calendar day the assignment is late.

**On-line components**

You can find additional course information from the course Web site. In addition, during the semester I will ask you to submit your assignments through METU-Online. You may log in to METU-Online system using your METU Id and passwords. Please do not forget to update your profiles (esp. your e-mail addresses).

**Method of Instruction**

ELE 430 is a lab-based course. The role of the instructor is to guide students through experiences that allow you to complete the project assignments of the course, and to act as a facilitator and supporter of your learning. Your success will be directly related to how much time and energy you put into the class, and your willingness to try new things. Do not expect things to run smoothly: the computers will crash, files will be corrupted, and other bad things will happen. Dealing with these situations is part of the class, and your ability to deal with them will impact your success in the class.

You are expected to take responsibility for your own learning and be willing to experiment with new technologies; to work with your classmates and the instructor to create a positive learning environment; to study assigned readings prior to each class session; to participate in class discussions and learning opportunities; and to complete all assignments on time and with the highest quality possible.

**Academic Ethics**

All assignments you hand in should be the result of your effort only. Academic

dishonesty, including any form of cheating and plagiarism will not be tolerated and will result in failure of the course and/or formal disciplinary proceedings usually resulting in suspension or dismissal. Cheating includes but is not limited to such acts as; offering or receiving unpermitted assistance in the exams, using any type of unauthorized written material during the exams, handing in any part or all of someone else's work as your own, copying from the Internet. Plagiarism is a specific form of cheating. It means using someone else's work without giving credit. Plagiarism is a literary theft. Therefore, you have to acknowledge the sources you use in your assignments.

#### **Tentative schedule and content**

|         | <b>Classes</b> | <b>Topic</b>                                                                                            |
|---------|----------------|---------------------------------------------------------------------------------------------------------|
| Week 1  | Feb 17-21      | Introduction and general information about the course; What does it mean to teach with dynamic geometry |
| Week 2  | Feb 24-28      | Introduction to Geogebra: Basic constructions.                                                          |
| Week 3  | Mar 3-7        | Lines and Angles                                                                                        |
| Week 4  | Mar 10-14      | Transformations, Symmetry, and Tessellations                                                            |
| Week 5  | Mar 17-21      | Triangles: Basic Explorations and Problems                                                              |
| Week 6  | Mar 24-28      | Quadrilaterals: Basic Explorations and Problems                                                         |
| Week 7  | Mar 31-Apr 04  | Polygons: Basic Explorations and Problems                                                               |
| Week 8  | Apr 07-11      | Circles: Basic Explorations and Problems                                                                |
| Week 9  | Apr 14-18      | Area: Basic Explorations and Problems                                                                   |
| Week 10 | Apr 21-25      | Similarity: Basic Explorations and Problems                                                             |
| Week 11 | Apr 28-May 02  | Trigonometry                                                                                            |
| Week 12 | May 05-09      | Preparing Teaching materials in Geogebra Project: Portfolio of teaching materials                       |
| Week 13 | May 12-16      | Project work                                                                                            |
| Week 14 | May 23- May 26 | Presentation of projects– Wrap up                                                                       |

## A.2 Syllabuses of ELE 435 Course

### ELE 435- SCHOOL EXPERIENCE I FALL 2011

**Section 01**  
Dr. Çiğdem Haser  
Monday 11.40 -12.30 at  
EF-10  
email: chaser@metu.edu.tr  
Office Hours: By  
appointment

**Section 02**  
Dr. Mine Işıksal  
Monday 11:40-12:30 at EF-  
34  
email: misiksal@metu.edu.tr  
Office Hours: By  
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**Graduate Assistants**  
Mustafa Alpaslan –  
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Seçil Karpuzcu – ysecil@metu.edu.tr  
Betül Yeniterzi – ybetul@metu.edu.tr

#### COURSE DESCRIPTION

Classroom observation including organization and management of school, daily activities in the school, group activities, a day of a teacher, a day of a student, school-family cooperation, observation of major and non-major courses, school and related problems, various teaching learning activities, examination of materials and written sources.

#### REQUIRED TEXTS

No text is required for this course. The instructor will assign some readings during the semester.

#### COMMUNICATION

Please, e-mail all your questions to your instructors and assistants, and check your METU e-mails regularly. Documents will be shared through METU ONLINE.

#### ATTENDANCE & PARTICIPATION

Students are expected to attend all class sessions unless they have a **documented** evidence of **medical excuse** preventing their attendance. Students are also expected to

arrive on time, and stay the entire class session. If you miss **three** (or more) class sessions without documented excuse, and/or if you establish a pattern of tardiness in class, the highest final grade you can earn in the class will be CC. Two instances of tardiness will be considered as being equivalent to one absence. If you have to miss a class because of an excused reason, it is your responsibility to provide instructor with evidence of doctor's visit no later than the next class session. After an absence, you should obtain class notes, hand-outs and other information from your classmates.

**IMPORTANT NOTE:** Students will not be assigned a final grade if they miss 5 or more class sessions with or without excused reasons. Thus, if you are sick for more than 4 class sessions, you may not pass the class regardless of your performance on the assignments and tests.

**Academic Misconduct:** Plagiarism will not be tolerated.

No additional points will be given at the end of the semester no matter what your excuse is.

### **POLICY ON LATE ASSIGNMENTS**

The expectation is that assignments will be turned in by the announced due dates. We will accept assignments after the due date but your grade will decrease by 10% of the allocated points for each calendar day the assignment is late. For example, a project worth 50 points that is turned in two days late will receive 10 fewer points (50 points x 10% per day x 2 days) than it would have if it had been turned in on time.

### **FIELD EXPERIENCE ATTENDANCE**

Attendance is mandatory. Do not miss any field experience day. If it happens, you should make it up. Your final letter grade will be FD if you miss one or more field day.

## **RESPONSIBILITIES & EXPECTATIONS OF STUDENTS**

- Complete appropriate number of days/hours as designated by the instructors.
- Model professional behavior/dispositions for the educational community.
- Complete all field and seminar assignments, self-evaluations, or site evaluations when required.
- Notify the course instructors of any and all absences, as well as dates to be rescheduled as soon as possible.
- Understand and observe rules and policies of each school site and classroom.
- Take all complaints to the course instructors.

## **TIPS FOR A SUCCESSFUL FIELD EXPERIENCE**

- Become familiar with your students' curriculum and your cooperating teacher's schedule.
- Assist the teacher with classroom activities and duties. This is a great way of helping your supervising teacher. (Remember you are a pre-service teacher and not an aide). Work with your Supervising Teacher to teach one of his/her lessons, consider taping this lesson for critiquing by yourself and/or the university instructor.
- Write a thank you note to your supervising teacher.
- Attend and participate in planning sessions.
- Attend and participate in at least one in-service.
- Review the school and classroom rules of your respective teachers.
- Always carry emergency contact information. Provide this to your cooperating teacher on the first day.
- Provide your cooperating teacher with your telephone number and/or electronic mail address in case he/she needs to contact you. Obtain his/her preferred contact information in case you need to reach him/her before the next scheduled field visit.



**ASSIGNMENTS** (A detailed rubric for evaluating your assignments will be shared during the semester.)

**Observation/Investigation Reports** (60 pts (30 pts each)/100)

You will be required to write two observation/investigation reports during the semester. These reports should be at most five-page long. They should be reflecting your true observations. You should not only describe what you have been observing, but also elaborate, critique, and reflect on the observation. **NONE OF THE OBSERVATION REPORTS ARE A ONE WEEK ACTIVITY. YOU SHOULD WRITE A REPORT BASED ON AT LEAST THREE WEEKS OF OBSERVATION!** You will be notified about the deadlines of these reports. Reports will be submitted to METU ONLINE and your file name should be: name\_surname\_435\_report1.doc (and relatively report2). The two observation reports and their requirements are as follows:

Observe the teaching of a mathematics concept and report what the learning difficulties are with specific examples from the teacher's and students' behaviors. What are the students' difficulties, what do they struggle to learn? How much do you think is related to the concept/students' background knowledge/students' studying skills/teacher?

You will be observing your teacher most of the time. Focus on how your teacher teaches a specific mathematics concept and how students learn it. Try to understand your teacher's way of teaching the concept. Which methods, if any, does your teacher use? Do you think his/her way of teaching is effective in students' learning? How are the students trying to learn the concept? Are all classroom activities (such as questioning, learning activities, solving exercises/problems on the board, quizzes, etc.) and out-of-class tasks (such as doing homework, completing worksheets, preparing posters, etc.) effective in students' learning? Why/why not? If you think that the students are learning, then how do you think a teacher can help them to learn?

Describe culture of the school and the class you observe the most. Try to understand the class and the school culture.

We want a description of the characteristics of the students, the teacher, the physical environment of the class and the school. How do the teacher and students communicate? How do students communicate each other? How do you think the classroom environment is different than what you have expected? How does the school culture look like? How do the administrators communicate the teacher and the students? How do the administrators and the teachers communicate the parents? Feel free to ask your teacher and the school administrators about these issues. Through these and other questions you have in your mind, we are hoping that you will have an understanding of the elements of the class and school culture. Try to find out how these elements might have impacted teachers' teaching and students' learning. THIS IS YOUR FINAL REPORT, BUT YOU WILL BE WORKING FOR THIS REPORT THROUGH THE SEMESTER.

***Learning Center Activity (30 pts/100):*** You are expected to prepare and implement a learning center in your practice school. This learning center will include 4-5 activities about specific curricular subjects. After implementing your learning center, you are expected to submit your materials and your experiences written as a report format.

***End of Semester Reflection Paper (10 pts/100):*** You will be asked to write a reflection paper on your school experience and what have you learned from this experience. This paper should include the responses to the following questions in the form of your reflections: What have you observed and experienced as expected and unexpected about the school context, students, and teachers? What might be the reason for unexpected issues? What was the most surprising issue for you during the semester? What were the difficulties you faced in your school, in the classroom, and in your own preparation? What do you think a student teacher (like you) need to know in order to handle this

course? What was the most educative experience for you? What was missing in this course which would help you in your school experience? What do you think you have learned in your cooperating school from the students, teachers, and the school context? What did you learn in our class hours?

For all your assignments, the following general issues will be considered for grading purposes:

Has the student done what was asked for and specified in the description of the assignment?

Are the ideas discussed relevant for mathematics teaching and learning?

Do they include important issues and discussions considered in the field of mathematics education?

Is the work clearly presented and properly written? Are the ideas well developed? Are they coherently woven together and presented in an orderly fashion?

Does the work demonstrate that the student spent time and thought in completing the assignment? Is the work thoughtful, insightful?

Has the student made connections to pertinent readings discussed in class and to the literature on the subject under study?

## APPENDIX B

### INTERVIEW PROTOCOLS

#### B.1 Dönem Başı Görüşme Soruları

1. Matematik dersinde teknoloji kullanımına yönelik hangi dersleri aldınız?
2. Geçen dönem aldığınız ELE 430 dersi finali için hazırladığınız projeden bahsedermisiniz? Hocanızdan ve arkadaşlarınızdan nasıl değerlendirmeler almıştınız?
3. Matematik öğretiminde teknoloji kullanımı ile ilgili, genel olarak ne düşünüyorsunuz?
  - Teknolojinin matematik öğretimindeki rolü nedir?
  - Öğrencilerin matematiksel kavramları etkili bir şekilde öğrenmeleri için, teknoloji eğitime nasıl entegre edilmelidir?
  - Teknoloji destekli iyi bir ders ile kötü bir dersi nasıl ayırt edersiniz?
4. Aldığınız derslerin, teknolojiyi hem teknik, hem de içerik açısından matematik dersine etkili bir şekilde entegre edebilmek için, size olan etkisini nasıl değerlendiriyorsunuz? Yeterli mi?
5. Teknoloji destekli matematik dersi planı hazırlama konusunda kendinizi nasıl değerlendiriyorsunuz?
6. Bu konuda daha fazla gelişmeye ihtiyacınız olduğunu düşünüyor musunuz? Hangi yönlerden?
7. Öğretmen olduğunuzda ders anlatırken teknoloji kullanmayı düşünüyor musunuz? Nasıl?
8. Sizi matematik öğretirken teknoloji kullanmaya motive eden şey nedir? Örnek verebilir misiniz?

9. Etkili bir teknoloji destekli matematik eğitimi için öğretmenlerin teknoloji kullanımı ile ilgili hangi temel bilgileri edinmiş olmaları gereklidir?
10. Etkili bir teknoloji destekli matematik eğitimi için öğrencilerin teknoloji kullanımı ile ilgili hangi temel bilgileri edinmiş olmaları gereklidir?
11. Benim sormadığım ama sizin eklemek istediğiniz bir soru var mı?

## **B.2 Dönem Sonu Görüşme Soruları**

1. Matematik öğretiminde teknoloji kullanımı ile ilgili, genel olarak ne düşünüyorsunuz?
  - Teknolojinin matematik öğretimindeki rolü nedir?
  - Öğrencilerin matematiksel kavramları etkili bir şekilde öğrenmeleri için, teknoloji eğitime nasıl entegre edilmelidir?
2. Teknoloji destekli iyi bir ders ile kötü bir dersi nasıl ayırt edersiniz? Teknoloji destekli matematik dersi planı hazırlama konusunda kendinizi nasıl değerlendiriyorsunuz?
3. Etkili bir teknoloji destekli matematik eğitimi için öğretmenlerin teknoloji kullanımı ile ilgili hangi temel bilgileri edinmiş olmaları gereklidir?
4. Öğretmen olduğunuzda ders anlatırken teknoloji kullanmayı düşünüyor musunuz? Nasıl? Profesyonel hayatınızda, üniversite eğitiminiz süresince öğrendiğiniz ne tür teknolojik becerilerinizi kullanmayı planlıyorsunuz?
  - Staj süresince uyguladığınız teknoloji destekli matematik derslerinin bu düşüncenize bir etkisi oldu mu?
  - Dönem içerisinde yaptığınız bütün bu uygulamaların, bir öğretmen olarak mesleki gelişiminize ve gelecekteki öğretmenlik yaşantılarınıza etkileri neler olacaktır?
  - Bu tecrübenin öğrencilere yaklaşımınızda herhangi bir farklılık yarattığını düşünüyor musunuz? Nasıl?

5. Bu konuda daha fazla gelişmeye ihtiyacınız olduğunu düşünüyor musunuz? Hangi yönlerden?
  - İleriye dönük olarak öğretim becerilerinizi teknolojik açıdan nasıl geliştirmeyi planlıyorsunuz?
6. Teknoloji entegrasyonu konusunda yetenekli öğretmen yetiştirmek için neler yapılabilir, önerinizleriniz var mı?
7. Benim sormadığım ama sizin eklemek istediğiniz bir soru var mı?

### **B.3 Uygulama Öncesi Görüşme Soruları**

1. Uygulama yapacağınız sınıftaki öğrenciler kaçınıcı sınıflar ve genel başarı durumları hakkında ne söyleyebilirsiniz?
2. Öğrencilerin teknolojik bilgileri hakkında ön bilgi edindiniz mi? Öğrencilerin teknoloji bilgi düzeyleri nedir? Öğrencilerin teknolojik bilgilerini geliştirmek için bir etkinlik yaptınız mı?
3. Hazırladığınız ders öğrencilerin seviyesine ve ön bilgilerine uygun mudur? Açıklayınız?
4. Bu dersin normal ders anlatımından farkı ne olacak? Teknoloji dersi nasıl etkileyecek? Teknolojiyi dersin hangi aşamasında, hangi amaçla kullanacaksınız?
5. Ders anlattığınız sınıfı, teknolojik açıdan dersinizi uygulamanız için gerekli olan kaynakları açısından nasıl değerlendiriyorsunuz?
6. Bu ders için hangi konuyu seçtiniz? Neden?
7. Öğrencilerin bu konuyu öğrenmeleri önemli midir? Neden?
8. Bu konu ve kavramları tercih etmenizde hangi faktörler etkili oldu? Diğer matematik konularının öğretiminde de bu programı kullanmak uygun olur muydu?

9. Bu konuyu tercih etmeniz teknoloji kullanımına yönelik özel bir nedeni var mı?
10. Dersi planlarken hangi kaynakları kullandınız? (Kitap, internet, dergi, eski ödevler, öğretmen yardımı ve diğer kaynaklar)
11. Derste dikkat etmeniz gereken en önemli hususlar nelerdir?
12. Derste kullanacağınız etkinlikleri kendiniz mi tasarladınız, yoksa hali hazırda olan bir ders planı üzerinden önemli noktaları düzenleyerek mi oluşturdunuz?
13. Bugünkü dersin kazanımlarından bahseder misiniz? Öğrenciler bu dersin sonunda ne/neler öğrenmiş olacaklar?
14. Teknolojiyi dersin hangi aşamasında ve nasıl kullanacaksınız?
15. Öğrenciler bir sonraki aşamada ne öğrenecekler? Bugün öğrendikleri bilgiler ileride hangi bilgileri öğrenmelerini kolaylaştıracak?
16. Planladığınız etkinliklerin bu konuyu anlatmak için ne derece yeterli olduğunu düşünüyorsunuz?
17. Hazırladığınız etkinliğin önemli noktaları nelerdir? Bu etkinlikte öğrencilerden tam olarak ne yapmalarını bekliyorsunuz?
18. Sizce hazırladığınız etkinlik/etkinlikler sınıfta nasıl sonuç verecek? Teknolojinin öğrencileri nasıl etkileceğini düşünüyorsunuz? Öğrencilerin dersin kazanımlarına ne derece ulaştıklarını belirlemek için ne yapmayı planlıyorsunuz?
19. Derste göstereceğiniz performans hakkında ne düşünüyorsunuz? Kendinizi ne kadar iyi hazırlanmış hissediyorsunuz ? (rahat hissediyorsunuz?)
20. Son olarak hazırladığınız ders planını genel olarak nasıl değerlendiriyorsunuz?
21. Benim sormadığım ama sizin eklemek istediğiniz bir soru var mı?

#### **B.4 Uygulama Sonrası Görüşme Soruları**

1. Derste neler oldu kısaca anlatır mısınız?

2. Ders anlattığınız sınıfı, teknolojik açıdan dersinizi uygulamanız için gerekli olan kaynakları açısından nasıl değerlendiriyorsunuz?
3. Eğitiminiz süresince aldığınız derslerin, teknolojiyi matematik dersine etkili bir şekilde entegre edebilmeniz açısından, size olan katkısını nasıl değerlendiriyorsunuz?
4. Teknoloji, seçtiğiniz konunun öğretimini nasıl etkiledi?
5. Ders anlatırken, teknoloji kullanmak konusunda kendinizi ne kadar rahat hissettiniz?
6. Dersin başarılı bulduğunuz bölümleri nelerdir? Bu derste kullandığınız hangi stratejileri sonraki derslerinizde de kullanacaksınız?
7. Dersin başarısız bulduğunuz bölümleri nelerdir? Yeniden uygulama yapma fırsatınız olsaydı değiştirmek, eklemek veya çıkarmak istediğiniz bir şey olur muydu?
8. Dersin uygulanması sırasında en çok zorlandığınız bölüm hangisiydi?
9. Planınızda olduğu halde uygulamadığınız bir bölüm var mı? Neden uygulamadınız?
10. Derste beklenmedik bir şekilde gelişen herhangi bir durum oldu mu? Neler yaptınız? Bu beklenmedik durumla başa çıkma konusunda kendinizi nasıl değerlendiriyorsunuz?
11. Hazırladığınız etkinlikte kullandığınız teknolojinin öğrencilerin öğrenmesini nasıl etkilediğini düşünüyorsunuz?
12. Genel olarak öğrencilerin derse tepkisi nasıl oldu? Bu beklediğiniz bir tepki miydi?
13. Derse sınıftaki öğrencilerin hepsinin katılımını sağlayabildiniz mi? Yoksa sadece bir grup öğrenci ile mi ders işlediniz? Neden?
14. Öğrenciler dersin kazanımlarına ne derece ulaştılar? Bu karara nasıl ulaştınız?
15. Sınıf yönetimini tehlikeye düşürecek bir durum oldu mu? Ne yaptınız?
16. Dersin her bir bölümü için zamanı etkili kullanabildiniz mi?



17. Dersinizi genel olarak nasıl deęerlendiriyorsunuz?
18. Bir sonraki uygulamada nelere dikkat edeceksiniz?
19. Benim sormadıęım ama sizin eklemek istedięiniz bir soru var mı?

## APPENDIX C

### OBSERVATION PROTOCOL

Gözlem Prokolü

Tarih:

Ders ve sınıf:

Öğretmen Adayı:

Gözlemci:

#### Gözlemciler İçin Yönlendirici Sorular

Aşağıdaki soruların cevaplarını bulmaya yönelik gözlemler yapmaya çalışınız. Gözlem notlarınızı alırken 5 dakikalık dilimleri de not ediniz.

1. Sınıfta kaç kişi var?
2. Sınıfın bir krokisini çizerek kendi yerinizi belirleyiniz.
3. Ders nasıl başlıyor? Öğretmen Adayı ne yapıyor ve ne söylüyor? Öğrenciler buna nasıl tepki veriyor? (Saat:\_\_\_\_\_)
4. Öğretmen adayı, teknolojiyi ne amaçla kullanıyor?
5. Öğretmen adayının dersin işlenişine yönelik sorduğu anahtar sorular nelerdir? Örneğin?
6. Öğrenciler öğretmen adayının soruduğu sorulara nasıl tepkiler reaksiyonlar veriyorlar? Cevaplarken teknoloji kullanıyorlar mı, örneğin?

7. Öğretmen adayı öğrencilerden gelen tepkilere nasıl karşılık veriyor? Teknolojiyi kullanıyor mu, örneğin?
8. Öğretmen adayı ders sırasında kitap ya da notlar kullanıyor mu? Öğrencilere ders sırasında ya da sonrasında üzerinde çalışacakları bir materyal veriyor mu?
9. Öğretmen adayı ne tip sorular soruyor? Sorulardan sonra cevaplar için bekleme zamanı veriyor mu? Öğrenciler nasıl cevap veriyor?
10. Öğrenciler ne tip sorular soruyorlar? Öğretmen adayı nasıl cevap veriyor?
11. Öğretmen adayı tahtayı ve diğer materyalleri (bilgisayar, GeoGebra, tepegöz) nasıl kullanıyor?
12. Öğretmen adayı sesini nasıl kullanıyor?
13. Öğretmen adayı göz temasında bulunuyor mu?
14. Öğretmen adayı önemli noktaları nasıl vurguluyor?
15. Ders sırasında tartışma oluyor mu? Hangi konular hakkında tartışma oluyor?
16. Öğretmen adayı dersi nasıl bitiriyor?

| Betimleyici Notlar (Descriptive Notes) | Yansıtıcı Notlar (Reflective Notes) |
|----------------------------------------|-------------------------------------|
|                                        |                                     |

## APPENDIX D

### TPACK LEVELS RUBRIC

|                                                                                                                     | <i>Recognizing (1)</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <i>Accepting (2)</i>                                                                                                                                                                                                                                      | <i>Adapting (3)</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <i>Exploring (4)</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <i>Advancing (5)</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|---------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>An overarching conception about the purposes for incorporating technology in teaching subject matter topics.</i> | <p>TI-Nspire technology is used for practice only, and all learning of new ideas done through the teacher mostly without technology</p> <p>TI-Nspire activities do not include inquiry tasks. TI-Nspire technology procedures concentrate on teacher demonstration and practice.</p> <p>TI-Nspire activities do not include inquiry tasks. TI-Nspire technology procedures concentrate on mathematical tasks with connections and inquiry activities that use or develop mathematical knowledge of high value: connections (especially between multiple representations) and strategic knowledge.</p> | <p>Larger part of TI-Nspire technology use is for demonstrations, which include presenting new knowledge</p> <p>TI-Nspire activities do not include inquiry tasks. TI-Nspire technology procedures concentrate on teacher demonstration and practice.</p> | <p>Teacher is using TI-Nspire technology in a way that is new and different from teaching without this technology (dynamic nature, linked representations) and used for learning new knowledge by students)</p> <p>TI-Nspire activities include inquiry tasks. TI-Nspire technology procedures concentrate on mathematical tasks with connections and doing mathematics – and on inquiry activities that use or develop connections (especially between multiple representations).</p> | <p>Larger part of TI-Nspire technology use is by students who explore and experiment with it for new knowledge and for practice</p> <p>TI-Nspire activities include inquiry tasks. TI-Nspire technology procedures concentrate on mathematical tasks with connections and doing mathematics – and on inquiry activities that use or develop mathematical knowledge of high value: connections (especially between multiple representations) and strategic knowledge.</p> | <p>TI-Nspire technology tasks provide students with deeper conceptual understanding of mathematics and its processes.</p> <p>TI-Nspire activities include inquiry tasks of high cognitive demand. TI-Nspire technology procedures concentrate on mathematical tasks with connections and doing mathematics – and on inquiry activities that use or develop mathematical knowledge of high value: connections (especially between multiple representations) and strategic knowledge.</p> |

## Continued

|                                                                                                                      |                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                          |
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| <p><i>Knowledge of students' understandings, thinking, and learning in subject matter topics with technology</i></p> | <p>TI-Nspire technology is used primarily for student practice.</p> <p>A TI-Nspire document does not present any new material, and only provides space for applications and drills.</p> | <p>TI-Nspire technology is mostly used for teacher demonstrations or teacher-led student-follow work with technology, it is rarely used for students' independent explorations.</p> <p>A TI-Nspire document mirrors the structure of the textbook presentation of mathematics without active explorations.</p> | <p>Teacher focuses on students' thinking of mathematics while students are using TI-Nspire technology on their own – both for learning new knowledge and review of prior knowledge</p> <p>A TI-Nspire document provides an environment for students to do mathematics with teacher guidance.</p> | <p>TI-Nspire teacher focuses on students' mathematics conceptual understanding and serves as a guide of student learning with technology, not a director.</p> <p>A TI-Nspire document provides an environment for students to deliberately take mathematically meaningful actions on objects. Teacher guidance is necessary in order for students to see the mathematically meaningful consequences of those actions.</p> | <p>Teacher facilitates students' high level thinking with TI-Nspire technology (linked representations, reasoning and proofs)</p> <p>A TI-Nspire document provides an environment for students to deliberately take mathematically meaningful actions on objects and to immediately see the mathematically meaningful consequences of those actions.</p> |
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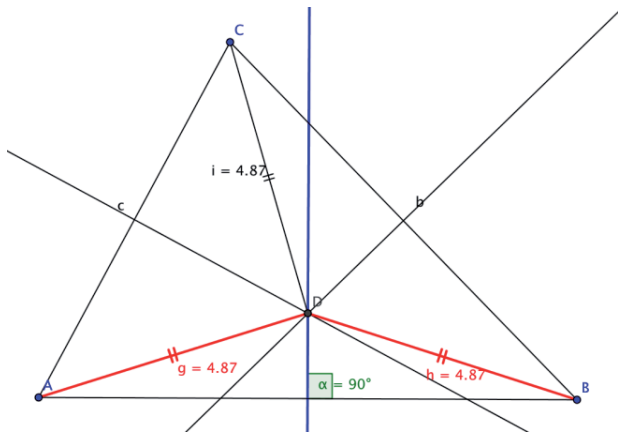
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|-----------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><i>Knowledge of curriculum and curricular materials that integrate technology in learning and teaching subject matter topics</i></p> | <p>Teacher does not use TI-Nspire technology for learning mathematics.</p> <p>TI-Nspire technology if used is not aligned with one or more curriculum goals.</p> | <p>Teacher uses standard approach to the curriculum topics with TI-Nspire technology being used as add-on.</p> <p>TI-Nspire technology is partially aligned with one or more curriculum goals. Teacher has difficulty in identifying topics in mathematics curriculum for including TI-Nspire Technology as tool.</p> | <p>The TI-Nspire technology is used as a replacement for non-technology based tasks in a traditional curriculum approach</p> <p>TI-Nspire technology is aligned with one or more curriculum goals. Teacher chooses topics from school mathematics curricula; however, TI-Nspire technology use is not always appropriate for the chosen curriculum topics.</p> | <p>Students are given problem solving tasks with TI-Nspire technology and are asked to expand math ideas on the basis of TI-Nspire technology explorations</p> <p>Technology is aligned with curriculum goals. Teacher chooses important topics of school mathematics curricula and technology use is appropriate for the chosen curriculum topics.</p> | <p>Teacher uses TI-Nspire technology in a fully constructive way, including tasks for development of higher level thinking and deepening understanding of mathematics concepts.</p> <p>TI-Nspire technology is strongly aligned with curriculum goals. Teacher chooses essential topics of school mathematics curricula. TI-Nspire technology use is effective for the chosen curriculum topics.</p> |
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| <i>Knowledge of instructional strategies and representations for teaching and learning subject matter topics with technologies</i> | <p>Teacher focuses on how to use TI-Nspire technology rather than how to explore math ideas, using teacher-directed lectures followed by student practice.</p> <p>TI-Nspire document provides students only with opportunities for drill and practice.</p> | <p>The instructions are teacher-led. Teacher structures lesson plan with limited student explorations with TI-Nspire technology.</p> <p>TI-Nspire document is not built around learning objects and does not promote student reflection.</p> | <p>Teacher uses, deductive (teacher-directed) approach with more focus on mathematics discoveries with TI-Nspire technology rather than inductive, traditional curriculum.</p> <p>TI-Nspire document is built around learning objects but does not promote student reflection – especially the posing of questions for sense-making.</p> | <p>Teacher uses various instructional strategies (deductive and inductive) and focuses on students thinking about mathematics. Teacher's use of TI-Nspire technology is beyond traditional approaches to curricular topics.</p> <p>TI-Nspire document is built around learning objects and must explicitly promote student reflection – especially the posing of questions for sense-making and reasoning, including explanation and justification.</p> | <p>Teacher focuses on students' hands-on and experimentation of new mathematics ideas with TI-Nspire technology, and focuses on conceptual development.</p> <p>TI-Nspire document is built around learning objects and must explicitly promote student reflection – especially the posing of questions for sense-making and reasoning, including explanation and justification.</p> |
|------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## APPENDIX E

### MELTEM'S ANSWER FOR WRITE UP PROBLEM 8



Flag should be positioned at the point D. I have drawn the perpendicular bisector of the side AB, then I know that any point on this line is the same distance from vertices A and B, which is a property of isosceles triangle. Then, I repeated this for the two other sides. Intersecting these perpendicular bisectors I found the point D that is the same distance from each vertex. Actually D is the orthocenter of the triangle ABC.



## APPENDIX G

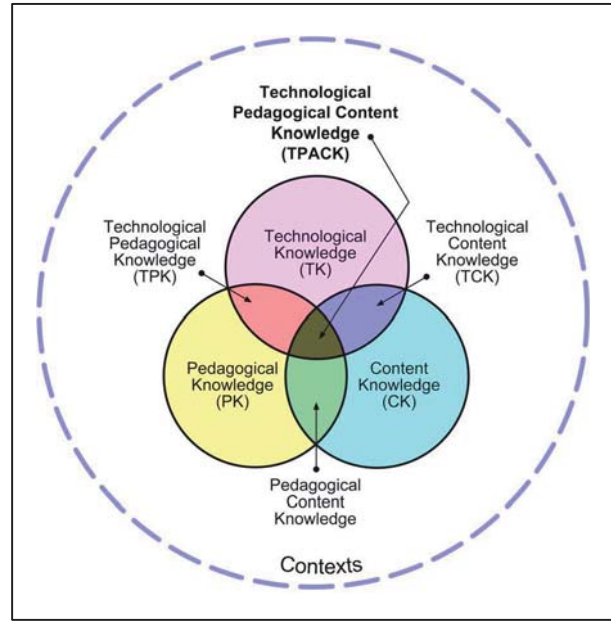
### TURKISH SUMMARY

#### Giriş

Öğretmen eğitimi çalışmalarının temelini, öğretmenlerin sahip olması gereken yeterlikler ve bu yeterliklerin kazanılması üzerine yapılan çalışmalar oluşturmaktadır (Ertmer, 2005). Shulman'ın (1986) ortaya koyduğu pedagojik alan bilgisi (PAB) teorik çerçevesi bu çalışmaların temelini oluşturmaktadır. Bu teoriye göre öğretmenlerin etkili bir öğretim uygulayabilmeleri için öncelikle derin bir alan bilgisine ihtiyaçları vardır. Daha sonra bir öğretmen olarak alan bilgisini uygulamaya dönüştürecek pedagojik bilgiye sahip olmaları gereklidir.

Son yıllarda, teknoloji alanında meydana gelen hızlı gelişim ve ilerlemeler, teknolojiyi sosyal ve iş yaşamımızın vazgeçilmez bir parçası haline getirmiştir. Teknoloji alanındaki bu hızlı değişim, eğitim alanını da etkileyerek, eğitim teknolojilerinin temellerini oluşturmuştur (Gülbahar, 2008). Eğitim ve öğretim etkinliklerinin desteklenmesi amacıyla kullanılan her türlü araç ve gereç eğitim teknolojisi kapsamında değerlendirilmektedir (Campbell, Peck, Horn ve Leigh, 1987; Gülbahar, 2008). Eğitim teknolojilerindeki gelişmeler, günümüz öğretmenlerinin bu teknolojiler hakkında bilgi sahibi olmalarını gerektirmektedir. Dolayısıyla bu durum öğretmen öğretmenlerin sahip olması gereken bilgi türlerine teknoloji bilgisinin de eklenmesi zaruriyetini doğurmuştur. Shulman'ın (1986) ortaya koyduğu pedagojik alan bilgisinin yanına eğitim teknolojisi bilgisi de eklenerek Koehler ve Mishra (2005) tarafından Tekno-Pedagojik Alan Bilgisi (TPAB) kuramı önerilmiştir. Bu kuram alan yazınında hala en çok kabul gören kuram olma özelliğini korumaktadır. İlgili literatür

incelendiğinde bu konudaki öncü çalışmaların kuramcılar tarafından yapıldığı görülmektedir. Bu kurama göre öğretmenlerin genel teknoloji okur yazarlığının yanı sıra uzmanlık alanlarına özel eğitim teknolojileriyle de ilgili olmaları ve eğitim süreçlerine dahil etmeleri gereklidir. Ayrıca, etkili teknoloji destekli eğitim ortamları tasarlayabilmeleri için teknoloji dünyasındaki hızlı geliştirmeleri takip ederek, teknolojik bilgilerini sürekli güncellemeleri gerekmektedir. Bu model teknolojik bilgiyi ön plana çıkararak, sınıf ortamında eğitim teknolojilerini etkili bir şekilde kullanabilen öğretmenlere ihtiyaç olduğunun önemine vurgu yapmıştır. Söz konusu kurama ait model Şekil 1’de gösterilmektedir.



Şekil 1. TPAB modeli (Koehler & Mishra, 2009, p. 63)

Bu model teknolojik bilgiyi ön plana çıkararak, sınıf ortamında eğitim teknolojilerini etkili bir şekilde kullanabilen öğretmenlere ihtiyaç olduğunun önemine vurgu yapmıştır.Yapılan çalışmalar aday öğretmenlere kendi alanlarına özel spesifik

eğitim teknolojilerinin kullanımı konusunda, uygulamalı olarak eğitim verilmesini tavsiye etmektedir (Koehler & Mishra, 2009; Koh & Divaharan, 2011; Niess, 2005). Öğretmenler artık özellikle uzmanlık alanlarında kullanılan eğitim teknolojilerin en etkili nasıl kullanılabileceği konusunda bilgi ve tecrübe sahibi olmalı ve öğreteceği konunun içeriğine ve öğrencilerinin seviyelerine en uygun olanını seçmelidir. Bu nedenle tekno-pedagojik eğitime göre eğitim fakültelerinin yeniden yapılandırılması (Çoklar, Kılıçer ve Odabaşı, 2007) ve öğretmen adayların mezun olmadan önce, eğitim teknolojilerini kullanabilecek yeterliklere sahip olmaları gereklidir. Uluslararası Eğitim Teknolojileri Topluluğu (International Society for Technology in Education) eğitim teknolojileri alanında öğretmenlerin ulaşması gereken standartları şu şekilde belirlemiştir. 1) Teknolojik kavram ve işlemler 2) Öğrenme ortam ve yaşantılarının planlanması ve tasarlanması 3) Öğrenme, öğretme ve öğretim programı 4) Ölçme ve değerlendirme 5) Verimlilik ve mesleki uygulama 6) Sosyal, etik, yasal ve insani konulardır. Öğretmen adaylarının bu yeterlikleri kazanıp belirtilen standartlara ulaşabilmeleri için gerekli düzenlemelerin yapılması gereklidir.

Dünya’da olduğu gibi Türkiye’de de eğitim teknolojilerinin etkili kullanımı için çalışmalar yapılmaktadır. Türkiye’de ideal öğretmenin sahip olması gereken yeterliklerin belirlenmesi amacıyla, Talim ve Terbiye Kurulu tarafından uygulamaya konulan Matematik Öğretmeni Özel Alan Yeterlikleri kapsamında (2008), bir matematik öğretmenin edinmesi gereken alt yeterlik alanlarında, matematik öğretiminde teknolojik kaynakları kullanabilme yetisinin önemi vurgulanmaktadır. Eğitim teknolojilerini eğitim süreçlerine etkili bir şekilde dahil etmek isteyen bir matematik öğretmeni, öğretimini destekleyici etkili öğrenme ortamları tasarlamak için gerekli teknolojik bilgiye sahip olmalı, özellikle kendi alanındaki eğitim teknolojileri hakkında okur yazar olmalıdır. Matematik öğretmeni ayrıca meslektaşlarıyla bir dayanışma içerisinde olmalı ve teknoloji bilgisini paylaşmalıdır. Yine benzer bir amaçla, Milli Eğitim Bakanlığı tarafından, 2006 yılında şimdiki adı Yenilik ve Eğitim Teknolojileri Genel Müdürlüğü (YEĞİTEK) olan ve öğretmenler için hizmetiçi eğitimler de

tasarlayan bir müdürlük kurulmuştur. YEĞİTEK eğitim teknolojilerinin eğitime entegrasyonu ve öğretmenlerin tekno-pedagojik alan bilgisini geliştirme konusunda çalışmalar yapmaktadır. Bu amaçla Fatih, İntel Öğretmen, İntel Öğrenci gibi projeler hazırlanarak öğretmenlerin gelişimlerine katkıda bulunmaktadır.

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 yapmıştır (Niess et al., 2007). Öğretmen adaylarının teknolojik, pedagojik ve alan bilgilerini kullanarak tasarladıkları derslerini, bir öğretmen olarak uygulama fırsatını bulabilecekleri yer okul deneyimi dersi kapsamında staj yapacakları okullardır. Okul deneyimi dersi bir öğrenme süreci olarak düşünüldüğünde, öğretmen adaylarının kendileri tarafından tasarlanan teknoloji destekli matematik derslerinin sınıf ortamındaki sonuçlarını, avantajlarını, dezavantajlarını görebilecekleri, bu anlamda eğitimlerini sağlayabilecekleri bir ortamdır. Öğretmen adaylarının öğretimlerini destekleyecek eğitimsel teknolojileri kullanmak konusunda kendilerini hazır hissetmeleri için, okul deneyimi dersi kapsamında uygulama yapma imkanı bulmaları gereklidir.

70'li yılların başında Schön tarafından ortaya atılan yansıtıcı düşünme aktiviteleri de öğretmen eğitiminde kullanılan, öğretmenlik uygulamalarını destekleyici bir metottur (Pakman, 2000). Schön (1987) yaşadıkları deneyimlerle ilgili olarak bireylerle görüşmeler yapılmasını ve bu deneyimin kendileri için olumlu ve olumsuz özelliklerinin farkettilmesinin önemine vurgu yapar. Bu bağlamda, bir örnek olay incelemesi olan bu çalışmanın, 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.

### **Çalışmanın Amacı**

Çalışmanın öğretmen adaylarının okul deneyimi dersinde yaptıkları teknoloji destekli matematik eğitimi uygulamalarının ve bu süreçte uygulanan yansıtıcı düşünme aktivitelerinin onların TPAB düzeylerine katkısını belirlemek amacıyla planlanmıştır. Ayrıca öğretmen adaylarının bu deneyime ilişkin genel görüşleri de paylaşılmıştır.

### **Çalışmanın Önemi**

Bu çalışma, alan yazınında öğretmen adaylarının TPAB gelişimi için önerilen, öğretmenlik uygulaması ve yansıtıcı düşünme aktivitelerinin, öğretmen adaylarının TPAB gelişimine olan olası katkılarının incelenmesi ve geri bildirim sağlaması açısından önemli olup, öğretmen eğitimi programlarının geliştirilmesine katkıda bulunduğu düşünülmektedir. Ayrıca çalışma GeoGebra dinamik geometri programının matematik öğretiminde kullanımına yönelik örnekler ve bu uygulamaların TPAB seviyeleri rubriğine göre değerlendirmelerini içermektedir. Somut örnekler, özellikle teknolojiye ilgisi olan öğretmenler için faydalı olacaktır.

### **Önemli Terimlerin Tanımları**

İlköğretim Matematik Öğretmen Adayları: 2011-2012 akademik yılı güz döneminde 4. Sınıfa devam eden Orta Doğu Teknik Üniversitesi İlköğretim Matematik Öğretmenliği bölümü öğrencileridir.

Teknolojik Bilgi: Bu çalışmada kullanılan eğitim teknolojisi GeoGebra dinamik geometri programı ve exceldir. Çalışmaya katılan öğretmen adaylarının bu teknolojileri teknik anlamda kullanmak için gerekli bilgiye sahip olmaları gereklidir.

*Tekno-pedagogik Alan Bilgisi (TPAB):* Bu çalışmada TPAB GeoGebra dinamik geometri programı ve excelin matematik öğretmek amacıyla etkili bir şekilde kullanılmasıdır.

*Yansıtıcı Düşünme Aktivitesi:* Çalışma kapsamında, her bir öğretmen adayı ile her dersin öncesi ve sonrasında öğretmen adayının dersten beklentileri ve dersin uygulanması neticesinde gerçekleşen olaylar hakkındaki görüşlerinin alınması amacıyla yapılan görüşmelerdir.

*Kolaylaştırıcı:* Yansıtıcı düşünme aktivitesini uygulamaya geçiren kişidir. Çalışmada bu rolü araştırmacı üstlenmiştir. Araştırmacı kendi kişisel düşüncelerinden arınık olarak, öğretmen adayına yaptığı teknoloji destekli uygulamanın olumlu ve olumsuz yönlerini düşündürmeye yönelik sorular sormuştur.

*Uygulama Deneyimi:* Uygulama deneyimi, öğretmen adaylarının Okul Deneyimi dersi kapsamında, Milli Eğitim Bakanlığına bağlı orta okullarda yaptıkları uygulamalardır. Bu çalışma kapsamında öğretmen adayları üçer defa teknoloji destekli matematik eğitiminde uygulama deneyimi kazanmıştır.

*Mentor Öğretmen:* Okul Deneyimi dersi kapsamında, Milli Eğitim Bakanlığına bağlı orta okullarda öğretmen adaylarına rehberlik eden öğretmenlerdir.

## **Yöntem**

### **Evren ve Örneklem**

Araştırma evrenini, Orta Doğu Teknik Üniversitesi (ODTÜ), Eğitim Fakültesi İlköğretim Matematik Öğretmenliği Bölümü 4. sınıf öğrencilerinden, ELE 430 kodlu dersi almış ve ELE 435 kodlu derse devam öğrenciler oluşturmaktadır. Bu çalışmanın katılımcıları dinamik geometri programının matematik dersinde etkili kullanımı

konusunda profesyonel eğitim almış, metot ve temel matematik derslerini tamamlamış öğretmen adaylarından oluşmaktadır. Araştırma datasının toplandığı 2011-2012 eğitim öğretim yılı güz döneminde bu koşulları sağlayan toplam 8 öğretmen adayı bulunmaktadır. Araştırmacı araştırmaya katılabilecek nitelikte olan bu 8 öğretmenin hepsine araştırmaya gönüllü olmaları için teklifte bulunmuş ve bu 8 öğretmenin 6'sından olumlu cevap almıştır. Araştırmanın örneklemi 4'ü kız 2'si erkek toplam 6 öğretmen adayından oluşmaktadır. Araştırma datası 6 öğretmen adayının katılımıyla toplanmıştır. Daha sonra örneklemden ders işleme performansı (TPAB düzeyleri rubriğine göre en iyi, orta ve en düşük seviye), cinsiyet ve dersin konusu (aynı konuyu anlatan öğretmen adaylarından birisi elenmiştir) kriterleri baz alınarak 2'si kız 1'i erkek olmak üzere toplam 3 öğretmen adayı seçilerek ayrıntılı analizler yapmak amacıyla araştırmanın katılımcıları belirlenmiştir.

### **Araştırma Soruları**

Bu çalışmanın üç tane araştırma sorusu vardır.

1. Öğretmen adaylarının sınıf ortamında uyguladıkları üç ayrı teknoloji destekli matematik eğitimi dersi için TPAB düzeyleri nelerdir?
2. Öğretmen adaylarının, okul deneyimi kapsamında uyguladıkları teknoloji destekli matematik eğitimi dersleri TPAB lerini ne ölçüde geliştirmiştir?
3. Öğretmen adaylarının araştırma kapsamında yasadıkları bu deneyim hakkındaki görüşleri nelerdir?

### **Araştırma Yöntemi**

Araştırmada nitel çalışmalarda kullanılan “örnek olay incelemesi” metodu kullanılmıştır. Örnek olay incelemesi bir çok veri toplama aracından elde edilen detaylı

veriler aracılığıyla bir olguyu derinlemesine inceleyen niteliksel bir araştırma türüdür (Creswell, 2007).

## **Veri Toplama Araçları**

Çalışma verileri görüşmeler, gözlemler ve ders uygulamaları video kayıtları ve adaylar tarafından hazırlanan dokümanlar aracılığıyla toplanmıştır.

## **Görüşmeler**

Araştırmada veri toplama amacı ile dört çeşit yarı yapılandırılmış görüşme formu oluşturulmuştur. Görüşme soruları araştırmacı tarafından alan yazınındaki benzer çalışmalar göz önünde bulundurularak hazırlanmış ve iki alan uzmanından görüş alınmış daha sonra pilot uygulamaları yapılarak son şekli verilmiştir. Araştırmada veri toplama amacı ile yapılan görüşmeler öğretmen adaylarının izniyle, daha sonra deşifre edilmek üzere, ses kayıt cihazı ile kayıt altına alınmıştır.

### *Dönem başı ve dönem sonu görüşmeleri*

Çalışmanın başında öğretmen adayları ile ilgili demografik bilgiler ve teknoloji hakkındaki genel düşüncelerinin alınması amacıyla birer görüşme yapılmıştır. Çalışmanın sonunda ise öğretmen adaylarının çalışma kapsamında yaşadıkları deneyime ilişkin olarak genel görüşlerinin alınması amacıyla birer görüşme daha yapılmıştır.

### *Ders Öncesi ve Sonrasında Yapılan Görüşmeler*

Öğretmen adayları ile her bir ders öncesinde ve sonrasında birer görüşme yapılarak dersin planına ve uygulanmasına yönelik görüşleri alınmıştır. Bu görüşmelerde öğretmen adayları kendi performanslarını değerlendirmiş ve sonraki görüşmelerde



önceki uygulamalarla karşılaştırma yaparak uyguladıkları derslerin başarılı ve başarısız yönleri üzerşne görüşlerini paylaşmışlardır.

### **Ders Uygulama Videoları ve Gözlem**

Her bir öğretmen adayı gerçek sınıf ortamında üç teknoloji destekli matematik eğitimi uygulaması yapmış ve bu uygulamalar öğretmen adaylarının izniyle video ile kayıt altına alınmıştır. Ayrıca katılımcıların uygulama okullarındaki ders uygulamaları bir gözlem protokolü eşliğinde gözlenmiştir. Ancak, bir katılımcının ders uygulamalarının video çekimine, özel okul yönetimi tarafından izin verilmemiş bu katılımcıların uygulama ile ilgili analizleri sadece gözlem notları üzerinden yapılmıştır. Bu katılımcının ders uygulamalarından birisi iki ayrı gözlemci tarafından gözlemlenerek gözlem notlarının tutarlılığı üzerine görüş birliğine varılmıştır.

Gözlem yapmanın bu çalışmadaki ikinci bir sebebi de ders uygulaması sonrasında yapılacak görüşmeye özel soru hazırlamaktır. Araştırmacı ders sonrası görüşmeleri için hazırladığı yarı yapılandırılmış görüşme formuna ek olarak, işlenen derste üzerinde durulması gereken önemli gördüğü noktaları gözlem yoluyla not almış ve görüşme formuna eklenmiştir. Bunun yanı nitel araştırmalarda gözlem notları, görüşme kayıtlarının tutarlılığını doğrulamak amacıyla da gereklidir.

### **Dökümanlar**

Çalışmada katılımcılar tarafından hazırlanan ders planları, okul deneyimi dersi kapsamında yazdıkları dönem sonu raporları da araştırmada veri olarak kullanılmıştır.

## **Veri Toplama Süreci**

Çalışma için veri toplama süreci 2011-2012 akademik yılı birinci döneminde başlamıştır. Çalışmaya gönüllü olarak katılmayı kabul eden katılımcılardan alan bilgisi, teknoloji bilgisi ve pedagojik bilgilerini birleştirerek staj okullarında teknoloji-destekli matematik uygulamaları yapmaları istenmiştir. Öğretmen adayları eğitimleri süresince aldıkları teknoloji destekli matematik eğitimi dersleri kapsamında özellikle ELE 430 Dinamik Geometri ve Uygulamaları dersinde kazandıkları teknolojik bilgilerden faydalanarak teknoloji destekli 3 tane matematik dersi planlamışlardır. Öğretmen adayları okul deneyimi dersinde planladıkları bu dersleri uygulamış ve dersin sonrasında uygulamalara yönelik görüşlerini paylaşmışlardır.

## **Data Analizi**

Elde edilen görüşme verileri deşifre edilmiş ve nitel veri analizi yöntemleri ile analiz edilmiştir. Data analizinin geçerlik ve güvenirlik çalışması için matematik ve teknoloji alanında alanında uzman bir araştırmacıdan aynı datayı kodlaması istenmiş ve tutarlılık sağlanmıştır.

Öğretmen adaylarının TPAB değişimlerini belirlemek için, sınıfıçi uygulamaları gözlem ve video kayıtları yardımı ile değerlendirilmiştir. Uygulama videoları ve gözlem notları verileri Matematik Öğretmenleri TPAB Standartları ve Gelişim Modeli'nden (Mathematics Teacher TPACK Standards and Development Model) uyarlanan bir kuramsal çerçeve ile analiz edilmiştir (Niess et al., 2009). Bu teorik çerçeve, öğretmen adaylarının TPAB'lerinin geliştirilmesi amacıyla sınıf ortamında yaptıkları teknoloji destekli matematik derslerinin değerlendirilmesine yönelik öneriler sunmaktadır. Lyublinskaya ve Tournaki (2011), Niess et al. (2009) in teorisine göre bir rubrik geliştirerek, bu alanda çalışan araştırmacılarının hizmetine sunmuştur. Bu çalışmada da öğretmen adaylarının TPAB düzeylerindeki değişim Lyublinskaya ve Tournaki

tarafından geliştirilen TPAB düzeyleri rubriği (2011) yardımıyla değerlendirilmiştir. Bu rubric 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. Geçerlik Güvenilirlik çalışması için alanda uzmanlık derecesi almış 10 yıllık ortaokul matematik öğretmeninden yardım alınmıştır. Uzman öğretmen, araştırmadan bağımsız olarak uygulama videolarını izlemiş ve Lyublinskaya ve Tournaki tarafından geliştirilen TPAB düzeyleri rubriği (2011) yardımıyla aday öğretmenlerin TPAB düzeylerini değerlendirmiştir. Ders videosu olmayan bir katılımcının derslerinin puanlanması için araştırması tarafından dakika dakika yazılan ayrıntılı betimlemeler, uzman öğretmene verilerek değerlendirmesini bu betimlemeler yardımıyla yapması istenmiştir. Daha sonra, araştırmacının değerlendirmeleriyle uzman öğretmenin değerlendirmeleri arasındaki tutarlılığı belirlemek amacıyla verilen puanlar üzerinden pearson product-moment correlation katsayısı hesaplanmıştır. Bu değer  $r(34) = .73, p < .01$  bulunmuştur. +1 ile -1 arasında değişen bu değer 0,70 ve üzeri değerde olduğunda puanların tutarlı olduğunu göstermektedir (Multon, 2010). İki araştırmacının puanları arasında % 73 oranında uyum vardır denilebilir.

### **Bulgular ve Tartışma**

Çalışmanın amacı, GeoGebra dinamik geometri programının matematik eğitime entegrasyonu konusunda eğitim alan öğretmen adaylarının okul deneyimi dersinde yaptıkları teknoloji destekli matematik eğitimi uygulamalarının ve süreçte dahil oldukları yansıtıcı görüşme aktivitelerinin, TPAB düzeylerine katkısını incelemektir. Çalışma kapsamında, öğretmen adaylarının bu deneyime ilişkin görüşleri alınmış ve rapor edilmiştir. Öğretmen adayları teknoloji destekli matematik öğretimi

uygulamalarında deneyim kazandıkça ve dersteki performanlarına yönelik değerlendirmeler yapıldıkça, ders uygulamalarının üç temel özelliğinde değişim gözlenmiştir.

Öğretmen adaylarının TPAB düzeylerinde iyileşme gözlenen bu özelliklerden birincisi dersin amacı, ikincisi öğretmen adayının konu ile ilgili öğrencilere yönelttiği soruların niteliği ve üçüncüsü de öğretmen adayının dersteki rolüdür. Örneğin Pelin isimli katılımcı ilk teknoloji destekli matematik eğitimi uygulamasında teknolojiyi ondalık sayılarda toplama ve çıkarma işleminin sonuçlarını kontrol etme amaçlı kullanmıştır. Öğrenciler derste, teknolojik aktiviteyi kullanarak cevaplarını kontrol etmişler ve verdikleri her doğru cevap için tebrikler pekiştirecini almışlardır, yanlış cevaplar içinse tekrar deneyiniz dönütü ile karşılaşmışlardır. Bu teknolojik aktivite dersi daha dikkat çekici hale getirip öğrencileri motive etmiş olsa da yeni matematiksel bilginin öğrenimi açısından öğrencilere katkı sağlamamıştır. Bu nedenle bu ders TPAB rubriğine göre en düşük düzeyde değerlendirilen bir ders olmuştur. Pelin dersten sonra yapılan görüşmede teknolojik aktivitenin öğrencileri motive ettiğini ancak yeni bir matematiksel bilgi öğretmediğini ifade ederek sonraki dersini planlarken teknolojiyi öğrencilere bir matematiksel bilgiyi öğretmek amacıyla dersine entegre edeceğini bildirmiştir. İkinci derste ise teknolojiyi öğrencilere üçgen eşitsizliği konusunu öğretmek amacıyla kullanmıştır. İkinci ders için öğrencilerini bilgisayar laboratuvarına götürmüş, bilgisayar başındaki öğrencilerden GeoGebra programını kullanarak verdiği üç uzunluğun üçgen oluşturup oluşturmadığını deneme yanılma yolu ile kontrol etmelerini istemiştir. Öğrencilerin büyük çoğunluğu deneme yanılma yolu ile verilen üç uzunluğun hangi şartlarda üçgen oluşturduğunu hangi durumlarda üçgen oluşturmadığını keşfetmişlerdir. Üçüncü derste ise özdeşliklerin geometrik modellerinin keşfine yönelik bir ders planlayıp eğitim teknolojisini bu modellerin görselleştirilmesi amacıyla kullanmıştır. Diğer iki katılımcının derslerinde de paralel bir değişim gözlenmiştir. Literatürde de olan benzer çalışmalarda benzer durumlar gözlenmiştir. Mudzimiri (2012) tarafından yapılan çalışmada öğretmen adayları öncelikle teknolojiyi alıştırma amaçlı

kullanmışlar daha sonra deneyim kazandıkça teknolojik aletin potansiyelini farkedip matematiksel bir kavramın keşfine yönelik teknolojik aktiviteler tasarlamışlardır. Mouza and Wong'un da (2009) ifade ettikleri gibi öğrenciler teknolojik, pedagojik ve alan bilgilerini harmanlayıp gerçek sınıf ortamında uygulamalar yaptıkça eğitim teknolojilerinin özelliklerinin farkına varıp onu daha etkili kullanmak için teknolojik bilgilerini geliştirirler.

Teknoloji destekli matematik eğitimi uygulamalarında değişim gözlenen bir ikinci özellik ise öğretmen adayının konu ile ilgili olarak öğrencilere yönelttiği soruların niteliğidir. Öğretmen adayları teknoloji destekli matematik eğitimi uygulamalarında deneyim kazandıkça ve dersteki performanlarına yönelik değerlendirmeler yaptıkça, sordukları soruların niteliği ve içeriğinde bir değişim gözlemiştir. Örneğin Ali isimli katılımcı ilk teknoloji destekli matematik eğitimi dersinde pisagor teoreminin ispatını anlatmış teknolojik aktivite ile pisagor teoreminin dinamik bir şekilde görselleştirmiştir. Öğrenciler dik kenarların kareleri toplamının hipotenüsün karesine eşit olduğunu gözlemlemişlerdir. Dinamiklik özelliği sayesinde de kenar uzunlukları değişse de bu eşitliğin bozulmadığını farketmişlerdir. Matematiksel konseptin görselleştirilmesi açısından öğrencilere oldukça yararlı olan bu uygulama, dersin işlenişinde matematiksel muhakeme gerektiren soruların sorulmaması nedeniyle düz anlatımla anlatılmıştır. Dolayısıyla öğrencilerin teoremi kendi kendilerine keşfetmelerine olanak sağlanamıştır.

Ders sonrasında yapılan görüşmede, öğretmen adayına bu durumla ilgili sorular yöneltilerek bu konudaki görüşleri alınmıştır. Görüşme sırasında sonraki derslerde öğrencileri matematiksel konseptler üzerinde düşündürmeye yönelik sorular sormak istediğini belirtmiştir. İkinci ders için Ali, ondalık sayıların tanımı ile ilgili bir teknolojik aktivite hazırlamıştı. Bu aktiviteyi sınıf ortamında uygularken ondalık sayıların geometrik modellerini görsel hale getirmiş ve öğrencilere model üzerinden ondalık sayıların büyüklüklerini karşılaştırmalarını gerektiren sorular sormuştur. Sorduğu sorular öğrencilerin verilen ondalık sayının geometrik modelini incelemelerini gerektiren sorulardı. Üçüncü ders için Ali cebirsel bir ifadenin çarpanlara ayrılması ile ilgili bir

teknolojik aktivite tasarlamıştı. Aktivitede cebirsel denklemin çarpanları birleştirilerek dikdörtgen şeklindeki geometrik modelin bütünü oluşturulmaktaydı. Sınıfta tartışma ortamı oluşturarak dinamik model yardımıyla parça bütün arasındaki ilişkiyi görsel olarak göstermiştir. Literatürde de teknoloji destekli matematik eğitimi uygulamalarında sınıf tartışmalarının önemini vurgulayan çalışmada Zbiek (2003) tartışma ortamının matematiksel konseptlerin öğrencilerin zihninde rasyonalize edilmesine katkı sağladığını belirtmiştir. Çalışmaya katılımcı olarak seçilecek öğretmen adaylarının sağlaması gereken kriterlerden birisi ELE 430 dersini araştırmaya katılmadan önce almış olmaları idi. ELE 430 dersinin hocası bu ders kapsamında yapılan teknolojik aktivitelerde, özellikle öğrencilere yöneltilmesi gereken soruların önemine vurgu yapmış ve aktivitelerde örnek sorular üzerinde tartışmalar yaptırmıştır. Öğretmen adaylarının gerçek sınıf uygulamalarından önce ELE 430 kodlu derste soru sorma becerilerinin geliştirilmesine yönelik yaptıkları etkinlikler sayesinde öğretmen adaylarının soru sorma becerilerine katkı sağlanmış olduğu düşünülmektedir. Daha sonra ilk uygulamada deneyimsizlikten dolayı soru sormanın önemine yeteri kadar konstre olamadıkları ancak deneyim kazandıkça daha sonraki uygulamalarda üst düzey öğrencileri düşündürmeye ve keşfe yönelik sorular sordukları belirlenmiştir.

Teknoloji destekli matematik eğitimi uygulamalarında değişim gözlenen özelliklerden üçüncüsü, öğretmen adayının dersteki rolüdür. Öğretmen adayları deneyim kazandıkça öğretmen merkezli öğretim yerine öğrenci merkezli eğitimi tercih etmeye başlamış sınıfta öğretici konumundan rehber konumuna geçmişlerdir. Örneğin, Meltem isimli katılımcının ilk teknoloji destekli matematik eğitimi için hazırladığı teknolojik aktivite öğrencilerin aktif olarak araştırıp keşfetmelerini gerektiren bir problem olarak tasarlanmışken, uygulamada Meltem'in hazırladığı soruların bir çoğunu sormaması ve bazı soruların cevaplarını öğrencilere yeterince süre vermeden kendisinin cevaplandırması nedeniyle dersin öğretmen merkezli işlenmesine neden olmuştur. Ders sonrasında yapılan görüşmede bu konuya dikkat çekilmiş ve öğretmen adayı dersi tam olarak planladığı şekilde işleyemediğini belirtmiştir. Meltem'in ikinci dersi bilgisayar

ortamında yapılmış ve öğrenciler her iki-üç kişiye bir bilgisayar düşecek şekilde konumlanmışlardır. Meltem'in hazırladığı teknolojik aktivite öğrencilere araştırma yapma şansı vermiş ve geometrik kuralı kendi kendilerine keşfetmelerine olanak tanımıştır. Ayrıca Meltem'in GeoGebra yardımıyla hazırladığı ipuçları, öğrenciler ihtiyaç duydukça adım adım verilerek matematiksel konsepti kendi kendilerine keşfetmelerine yardımcı olunmuştur. İkinci ders uygulamasında Meltem'in rolü öğreticiden çok öğrencilere rehber olmaktı. GeoGebra programı ile bir gerçek hayat problemini modelleyen Meltem, program yardımıyla öğrencilere problemin çözümüne yönelik ip uçları sunmuş, öğrencilerin problem çözme süreçlerine rehberlik etmiştir. Üçüncü ders için Meltem yine öğrencilerin kendi kendilerine öğrenmelerine olanak tanıyan teknolojik aktiviteler tasarlamıştı. Bu derste de daha çok rehber rolünü üstlenmiş öğrencilerin ihtiyaçları doğrultusunda onları yönlendirmiştir. Zbiek (2003) de eğitim teknolojilerinin öğrencilerin matematiksel düşünme ve muhakeme güçlerini kullanmalarını sağlayacak olanağı öğretmene vererek onun derste rehber rolünü üstlenmesini sağlayacağını belirtilmiştir. Araştırmaya katılan üç öğretmen adayının üçünün de TPAB düzeylerinin birinci uygulamadan üçüncü uygulamaya Lyublinskaya ve Tournaki'nin (2011) geliştirdiği rubriğe göre yükseldiği gözlemlenmiştir.

Çalışmanın diğer bir amacı ise öğretmen adaylarının yaşadıkları bu deneyim hakkındaki görüşlerinin belirlenmesidir. Öğretmen adayları teknoloji destekli matematik eğitimi uygulamalarının ardından yeniden bir görüşme yapılarak yaşadıkları bu deneyime ilişkin değerlendirmeleri alınmıştır. Daha sonra bu görüşlerin nitel veri analizinden çıkan 13 tema üç kategoride değerlendirilmiştir. Bu kategorilerden birincisi, ders hazırlığıdır. Ders hazırlığı kategorisinin içerdiği temalar; öğrencilerin ön bilgileri, dersin kazanımları, dersliğin teknolojik açıdan donanımı, teknoloji kullanımının konu anlatımı açısından ne kadar gerekli olduğu ve teknolojinin öğrenci motivasyonundaki rolüdür. Öğretmen adaylarına göre bir teknolojik aktivite planlanırken öncelikle öğrencilerin ön bilgileri göz önünde bulundurulmalıdır. Eğitim teknolojisi kullanılarak işlenmek istenen konunun amacına ulaşması için teknolojik aktivite hem konu ile ilgili

öğrencinin ön bilgilerine uygun, hem de öğrencilerin teknolojik bilgis düzeyine uygun olmalıdır. Ek olarak dersin labaratuvar ortamında mı yoksa sınıf ortamında mı işlenmesinin daha uygun olduğuna dersin kazanımlarına ve aktivitenin hazırlanış amacına göre karar verilmelidir. Örneğin, dersin kazanımı aktiviteyi öğrencilerin kendi kendilerine adım adım inşa etmelerini gerektiriyorsa laboratuvarda, öğretmenin matematiksel konsepti görselleştirmek için hazırladığı bir aktiviteyse, sınıf ortamında sunulması daha uygun olacaktır. Öğretmen adayları ayrıca eğitim teknolojilerinin öğrencilere dört işlem yaptırmak ve motive etmek için amaçlı değil, konunun öğretimini desteklemek amacı ile kullanılması gerektiğini belirtmişlerdir. Ayrıca öğretmen adayları, GeoGebra dinamik geometri programı, matematiksel konseptlerin görselleştirmesine (ör. üç boyutlu cisimlerin açık gösterimi, cebirsel ifadelerin dinamik olarak geometrik açılımlarının gösterilmesi, fonksiyonların grafiklerinin çizilip, tablolarını oluşturarak çoklu temsillerle gösterilmesi ve grafikte değişkenler değiştirildiğinde grafiğin görüntüsünün nasıl değiştiğinin gösterimi) olanak sunarak hem öğretmenlere ders anlatmakta kolaylık hem de öğrencilerin matematiksel kavramları anlamalarına katkı sağlamak amacıyla kullanılması gerektiğini belirtmişlerdir.

Kategorilerden ikincisi ise dersin uygulama sürecidir. Uygulama sürecinin içerdiği temalar ise; araç, öğretmen rolü, çalışma yaprağı, sınıf yönetimi, zaman yönetimi ve uygulama deneyimidir. Çalışmaya katılan öğretmen adayları, eğitim teknolojilerini öğretmene yardımcı olan etkili bir araç olarak tanımlamışlardır. Teknoloji destekli bir derste, öğrencilerin teknolojiye değil, matematiksel konsepte odaklanmasını sağlayan etkinlikler tasarlanması gerektiğini bildirmişlerdir. Kısacası, katılımcılara göre teknoloji matematik eğitiminde amaç değil araç olmalıdır. Ayrıca öğretmen adayları teknoloji destekli eğitim yapılırken öğretenden değil, öğrencilerin öğrenmelerine rehberlik eden bir rol üstlenmesi gerektiğini bildirmişlerdir. Ek olarak öğretmen adayları, öğretmenlere öğrencilerin derse takibini kolaylaştırmaları için çalışma yaprakları hazırlamalarını önermişlerdir. Öğretmen adayları teknolojinin sınıf ortamında kullanılmasının teknik problemleri de beraberinde getirdiğinin altını çizerek, böyle bir



durumla karşılaşıldığında teknik problemlerin çözümü ile zaman kaybetmek yerine, teknoloji destekli işleyecekleri derslere b planı ile gitmeleri gerektiğini ifade etmişlerdir. Paralel olarak öğretmenler derslerinde teknoloji kullanacaklarsa eğer dersten önce mutlaka teknik donanımın olası teknik problemlere karşı kontrol edilmesi gerektiğini belirtmişlerdir. Bu gibi durumlar derslerinde teknoloji kullanan öğretmene dersten önce teknolojik aksamı kontrol etme, ders sırasında çıkacak herhangi bir teknik probleme hazırlıklı olma gibi ekstra sorumluluklar yükleyerek bir yandan da öğretmenlerin iş yükünü artırdığını bildirmişlerdir.

Bu kategorilerden üçüncüsü ise mentorluktur. Mentorlupun içerdiği temalar ise; kolaylaştırıcı ve tavsiyelerdir. Öğretmen adayları, her bir dersin öncesinde ve sonrasında dersin değerlendirilmesine yönelik görüşmeler yapılmasına olumlu tepki göstermiş, bu sayede dersin olumlu ve olumsuz yönleri üzerine düşünme fırsatı bulduklarını belirtmişlerdir. Bu kritikler neticesinde bir sonraki derste nelere dikkat etmeleri gerektiğinin bilincine vardıklarını ve ona göre önlem aldıklarını belirtmişlerdir. Öğretmen adayları böyle bir süreçten geçtikten sonra teknoloji destekli eğitim yapmaya yönelik öz güvenlerinde bir artış olduğunu ve uygulama yaptıkça derste neler olacağı, öğrencilerin ne tür tepkiler vereceği ile ilgili daha sağlıklı öngörülerde bulunduklarını belirtmişlerdir. Öğretmen adayları ayrıca bu tür gerçek sınıf ortamında teknoloji destekli öğretim yapma tecrübesini her öğretmen adayının deneyşmlemesi gerektiğini bildirmişlerdir. Öğretmen adayı mezun olmadan önce gerçek sınıf ortamında teknoloji destekli matematik eğitimi uygulamaları yaparak, öğrendiği bilgi ve becerilerini uygulamaya geçirerek potansiyelinin farkına varmalıdır. Öğretmen adayları, kendi hazırladıkları teknoloji destekli aktiviteleri gerçek sınıf ortamında uygulama fırsatı bulduklarında, teknolojinin öğretimlerine nasıl katkı sağladığını ve hangi açılardan dezavantajlı olduğunu tecrübe etmelerinin, öğretmen olduklarında daha isabetli öğretimsel kararlar almalarını sağlayacağını belirtmişlerdir.

## Doğurgalar

Bu çalışmada öğretmen adayları tekno-pedagojik alan bilgilerini kullanarak gerçek sınıf ortamında teknoloji destekli matematik dersleri uygulamışlar ve bu deneyimin bir öğretmen olarak kendilerine olan katkıları hakkındaki görüşlerini paylaşmışlardır. GeoGebra dinamik geometri programının matematik eğitiminde kullanımını hakkında eğitim almış öğretmen adaylarına, öğrendikleri yeni bilgi, beceri ve metotları gerçek sınıf ortamında ilköğretim öğrencileriyle uygulama fırsatı verilerildiğinde ve uygulamaların öncesi ve sonrasında yansıtıcı tartışma yaptırıldığında, tekno-pedagojik bilgi açısından geliştikleri ve öğretmen olarak kendilerindeki değişimi ve gelişimi farkettileri belirlenmiştir. Araştırma sonuçlarının, öğretmen adaylarının TPAB'lerini geliştirmeye yönelik geri bildirim sağlaması nedeniyle öğretmen eğitimi programlarına katkı yapacağı umulmaktadır. Öğretmen adaylarının, deneyim kazandıkça ve derste olanların üzerine konuştukça dersin amacı, öğrencilere yöneltilen soruların niteliği ve dersteki rollerinde bir değişim olduğu ve bu değişimin, TPAB değerlendirme rubriğine göre TPAB düzeylerine katkı sağladığı düşünülmektedir. Deneyimleriyle ilgili olarak yapılan görüşmelerin analizine göre, öğretmen adayları, eğitim teknolojilerini, öğretimlerini destekleyen ve öğrencilerinin derse olan motivasyonunu artıran bir araç olarak görmektedirler. Bu nedenle öğretmen adaylarının tekno-pedagojik yeterlilikleri hakkında bilgi sağlamak için gerçek sınıf ortamında uygulamalar yapmaları ve uygulama sürecindeki gelişimlerinden haberdar edilmelidirler. Ek olarak, Milli Eğitim Bakanlığı tarafından öğretmenlere verilen eğitim teknolojileri ile ilgili hizmetiçi kurslarının geliştirilmesine katkıda bulunması beklenmektedir.

### **Araştırmanın Sınırlılıkları**

Bu çalışmanın, araştırma sonuçlarının genellenmesini engelleyici sınırlılıkları vardır;

- Araştırmaya katılan öğretmen adaylarının Türkiye'nin en yüksek puanla öğrenci alan üniversitelerinden biri olan Orta Doğu Teknik Üniversitesi'nde eğitim görüyor olmaları, araştırma sonuçlarının genellenmesini sınırlandırmaktadır.
- Bu çalışmaya katılan öğretmen adaylarına ekstra olarak bir eğitim verimemiş. Eğitimleri süresince aldıkları alan, pedagoji ve teknoloji ile ilgili derslerin TPAB gelişimleri için gerekli alt yapıyı oluşturduğu varsayılmıştır.
- Ders kazanımları, müfredatın aksamaması amacıyla, öğretmen adaylarına çoğunlukla mentor öğretmen tarafından önerilmiştir.
- Uygulama deneyimi, uygulama okullarında yapılan 5-6 saatlik uygulamalarla sınırlıdır.
- Araştırmada kullanılan eğitim teknolojileri GeoGebra dinamik geometri programı ve excel ile sınırlıdır.
- Uygulama okullarında uygulamaların bazılarının yapıldığı bilgisayar laboratuvarları, bilgisayar dışında teknik bir donanımı olmayan, oturma planının değiştiremediği, grup çalışması ve tartışmaların çok sağlıklı bir şekilde yürütülemediği ortamlardır.
- Bir örnek olay incelemesi olan bu çalışma da sadece üç öğretmen adayının sonuçları rapor edilmiştir. Araştırma sonuçlarının genellenmesi mümkün değildir.
- Araştırmacının çalışmada kolaylaştırıcı olarak görev yapması, araştırma sonuçlarının yanlı olmasına neden olmuş olabilir.

- Veri toplama sırasında öğretmen adaylarının TPAB bilgilerini kullandıkları ve mülakatlar sırasında soruları samimiyetle cevaplandıkları kabul edilmiştir.

### **İleriki Çalışmalar için Öneriler**

Günümüz matematik öğretmeninden eğitim teknolojilerini derslerinde etkili bir şekilde kullanıyor olmaları beklenmektedir. Bu anlamda öğretmen yetiştirme programlarında yenileşme sürecine girilerek, daha nitelikli teknoloji desteğinin eğitime nasıl entegre edileceğine yönelik çalışmalara yer verilmelidir. Bu konuda nitelikli öğretmen yetiştirilmesi ve gerekli alt yapının oluşturulması amacıyla bakanlık boyutunda gerekli düzenlemelerin yapılmasının eğitimde teknoloji kullanımı çalışmalarına katkı sağlayacağı düşünülmektedir. Bu nedenle ilk olarak eğitim programlarında teknoloji destekli derslerin niteliği geliştirilmeli ve bu konudaki zorunlu ders sayısı artırılmalıdır. Eğitim teknolojilerinin matematik eğitiminde kullanımına yönelik derslerin içerikleri metot dersi ile desteklenmelidir.

Araştırma sonuçları göstermiştir ki; yansıtıcı düşünme aktiviteleri ile desteklenmiş teknoloji destekli matematik eğitimi uygulamaları, öğretmen adaylarının TPAB gelişimlerinde önemli katkılar sağlamaktadır. Öğretmen adaylarına, dersler aracılığıyla kazandıkları tekno-pedagojik bilgilerin uygulamaya geçirilmesine olanak tanıyacak fırsatlar verilmelidir. 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. Ders uygulamasının öncesi ve sonrasında yapılan bu görüşmelerin tekno-pedagojik alan bilgisinin gelişimine katkıda bulunmasının yanı sıra, sonraki uygulamalarda önceki uygulamalarda yapılan hataların tekrarlanmasını engellemektedir.

Okul deneyimi dersi kapsamında öğretmen adaylarına rol model olmaları gereken mentor öğretmenler için de tekno-pedagojik alan bilgilerini geliştirici hizmetiçi eğitimler

gereklidir. Öğretmen adaylarının profesyonel iş yaşamına başlamadan önce teknoloji kullanımı açısından etkili örnekler izlemesi ve mentor öğretmeni ile bilgi alış verişinde bulunabilmesi açısından bu eğitimler gereklidir. Öğretmen yetiştirme ve hizmet içi eğitim programlarında bu konuların ele alınması önem arz etmektedir.

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## APPENDIX F

### CURRICULUM VITAE

#### PERSONAL INFORMATION

Surname, Name: Balgalmış, Esra

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#### EDUCATION

| Degree      | Institution                                               | Year of Graduation |
|-------------|-----------------------------------------------------------|--------------------|
| MS          | Gaziosmanpaşa University,<br>Educational Sciences         | 2007               |
| BS          | Hacettepe University, Elementary<br>Mathematics Education | 2003               |
| High School | Anatolian Teacher Training High<br>School                 | 1999               |

#### VISITING SCHOLAR

|                     |                            |                        |
|---------------------|----------------------------|------------------------|
| February 2012– 2013 | Ball State University, USA | Mathematics Department |
|---------------------|----------------------------|------------------------|



## WORK EXPERIENCE

| Year                             | Place                                                         | Enrollment                           |
|----------------------------------|---------------------------------------------------------------|--------------------------------------|
| 2007 September-<br>Present       | METU Department of Elementary<br>Education                    | Research Assistant                   |
| 2007 February-<br>2007 September | Gaziosmanpasa Universiy<br>Department of Educational Sciences | Research Assistant                   |
| 2003-2007<br>February            | Turkish Ministry of National<br>Education                     | Middle School<br>Mathematics Teacher |

## FOREIGN LANGUAGES

English

## PUBLICATIONS

### Journal Article

Baloğlu, M., & **Balgalmış, E.** (2013, in press). A multivariate investigation of coping strategies among school administrators. *H. U. Journal of Education*. (SSCI)

Baloğlu, M., & **Balgalmış, E.** (2010). The adaptation of the mathematics anxiety rating scale-elementary form into Turkish, language validity, and preliminary psychometric investigation. *Educational Sciences: Theory and Practice*, 10(1), 101-110. (SSCI)

**Balgalmış, E.,** & Baloğlu, M. (2010). A comparative study of educational administrators' thinking styles in relation to different variables. *H. U. Journal of Education*, 38, 01-10. (SSCI)

Baloğlu, M., & **Balgalmış, E.** (2005). The description of self-values among primary-and-high school administrators. *Journal of Values Education*, 3 (10), 19-31.

#### **National and International Conference Presentations**

**Balgalmış, E.**, Shafer, K., Cakiroğlu, E., “*Elementary Teachers’ Consideration of Technology Integration into Mathematics Education with in the Context of Their Teaching Practices*”. Proceedings of Eighth Congress of European Research in Mathematics Education 2012. Side/Antalya/ Turkey : CERME 8, (2013).

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**Balgalmış, E.** “*Misconceptions of Elementary School Students in Algebra*”. Paper presented at the annual meeting of the European Conference on Educational Research, Berlin, Germany, (2011).

**Balgalmış, E.**, Durmus, T., and Mehmetlioglu, D., “*Math anxiety level of elementary school studets’ in Turkey*”. Paper presented at the annual meeting of the European Conference on Educational Research, Helsinky, Finland, (2010).

## APENDIX H

### TEZ FOTOKOPİSİ İZİN FORMU

#### ENSTİTÜ

Fen Bilimleri Enstitüsü

☐

Sosyal Bilimler Enstitüsü

☒

Uygulamalı Matematik Enstitüsü

☐

Enformatik Enstitüsü

☐

Deniz Bilimleri Enstitüsü

☐

#### YAZARIN

Soyadı : Balgalmış

Adı : Esra

Bölümü : İlköğretim

**TEZİN ADI** (İngilizce) : An Investigation of Pre-Service Elementary Mathematics Teachers' Techno-Pedagogical Content Knowledge within the Context of Their Teaching Practices

**TEZİN TÜRÜ** : Yüksek Lisans

☐

Doktora

☒

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir.

☐

2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir.

☐

3. Tezimden bir (1) yıl süreyle fotokopi alınamaz.

☒

**TEZİN KÜTÜPHANEYE TESLİM TARİHİ:**