PRE-SERVICE TEACHERS' TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE DEVELOPMENTIN A COMPUTER-ASSISTED MATHEMATICS INSTRUCTION COURSE

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Thesis Abstract

Nazmi Erdoğan, "Pre-service Mathematics Teachers' TPACK Development in a Computer-assisted Mathematics Instruction Course"

In Turkey there is a policy to integrate technology into education. Classrooms have been equipped with interactive white boards, internet networks, and tablet computers. In this process, it is essential for pre-service teachers to know how to use technology for educational purposes. The aim of this thesis is to investigate pre-service mathematics teachers' technological, pedagogical, and content knowledge (TPACK) development in a computer assisted mathematics course. The need to train pre-service teachers as capable of using technology for teaching makes this research important. This research was based on collection and analysis of both quantitative and qualitative data. Qualitative part of this research was a case study. Quantitative data were collected from 29 pre-service teachers with a TPACK Survey. Qualitative data were collected from 6 pre-service teachers by interviewing and observing throughout the course. Findings from this research show that it is possible for a university course to develop pre-service teachers' TPACK and this development is related to given technology, various personal factors of pre-service teachers, group work among them, and the structure of the course. This thesis presents recommendations regarding content specific technology related courses and collaboration among pre-service teachers in these courses in order to support their TPACK development.

Tez Özeti

Nazmi Erdoğan, "Matematik Öğretmen Adaylarının Bilgisayar Destekli Matematik Öğretimi Dersi Kapsamında Teknolojik Pedagojik Alan Bilgilerinin Gelişimi"

Türkiye eğitim sistemine teknolojiyi entegre etmeye yönelik bir politikaya sahiptir. Bu amaçla sınıflara etkileşimli tahtalar konulmakta, sınıflara internet ağları kurulmakta ve öğrencilere tablet bilgisayarlar dağıtılmaktadır. Tüm bu süreç öğretmen adaylarının, teknolojinin öğretim amacıyla nasıl kullanılacağını bilmelerini zorunlu kılmaktadır. Bu tezin amacı matematik öğretmen adaylarının bilgisayar destekli matematik öğretimi dersi kapsamındaki teknolojik, pedagojik, alan bilgilerindeki (TPAB) gelişimlerini incelemektir. Bu çalışmayı önemli hale getiren nokta teknolojiyi öğretim amacıyla kullanabilecek yeterliliğe sahip öğretmen adayları yetiştirebilmeye yönelik olan ihtiyaçtır. Bu çalışmada nicel ve nitel veriler toplanarak analiz edilmiştir. Çalışmanın nicel verileri Şahin (2011) tarafından geliştirilen TPAB ölçeği ile 29 öğretmen adayından toplanmıştır. Çalışmanın nitel verileri ise 6 öğretmen adayından görüşmeler ve ders boyu devam eden gözlemler neticesinde toplanmıştır. Bu çalışmanın sonuçlarına göre bir üniversite dersi kapsamında çalışmaya katılmış olan öğretmen adaylarının TPAB'lerinin geliştirilmesi mümkün olmuştur ve bu gelişim verilen teknolojiyle, bazı kişisel faktörlerle, öğretmen adayları arasındaki grup çalışmasıyla ve dersin yapısıyla ilişkili bulunmuştur. Bu tezin sonuçları teknolojik öğretimi dersinin alana özel olmasının ve öğretmen adayları arasında ders boyunca kullanılacak işbirliğinin onların TPAB'lerinin gelişimlerine olumlu anlamda katkı sağlayacağını göstermektedir.

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To Engin Ader,

for his support, encouragement, and

everything he taught me

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CHAPTER1

INTRODUCTION

Background of the Problem

The classrooms of the twenty-first century are equipped with technological tools such as computers and internet networks. Therefore there is a need for competent teachers to use technology for supporting students' learning in classrooms. Teachers must design appropriate learning environments for students' learning. Therefore teachers are required to have necessary pedagogical skills, attitudes, and especially knowledge to use technology in order to promote students' learning. If teachers don't have these competencies, educational aims cannot be achieved even in a technology rich environment. Many teachers have tendency to teach as they were taught. Expecting them to integrate technology without knowledge causes challenges to teachers. For overcoming those challenges, teachers must be given content-specific professional development opportunities. Moreover teachers need time during the school day in order to use instructional technology with their colleagues, to attend workshops, seminars and conferences. Professional learning communities such as Ohio Learning Network help teachers to discuss issues on integration of technology to classroom settings. These discussions make teachers more comfortable to solve problems in the process of technology-integration (Keengwe & Onchwari, 2011). In this process, teachers need to know about using technology for educational purposes. Teachers need support for the formation and development of knowledge to adapt

technology into education. In other words teachers should be aware of how technological tools are used for satisfying educational objectives. Attempts for making teachers competent to integrate technology in education significantly contribute to teachers' knowledge to use technology as stated in literature (e.g., Koehler & Mishra, 2005).

Formation and development of knowledge to integrate technology into education requires a process for teachers. Namely teachers need time and support to gain knowledge to integrate technology into education. For this aim, teachers may be supported with in-service trainings. Teacher training programs have responsibilities to educate pre-service teachers as the ones who can use technology in teaching process. Namely, pre-service teachers' knowledge development about integrating technology into education must be a part of teacher training programs of universities (Anthony & Clark, 2011; Grandgenett, 2008). Teacher training programs must provide pre-service teachers with the opportunity of developing their knowledge about using technology for educational purposes. Therefore pre-service teachers have chance to graduate from universities as teachers who are capable of integrating technology into education. If classrooms are equipped with technological tools and materials, teachers must know how to use technology for educational purposes. Teacher training programs have responsibility to give all potential knowledge to pre-service teachers that enable them to integrate technology into education.

Significance of the Problem

In Turkey, Ministry of Education's (MEB) vision about Information and Communication Technologies (ICT) is "to integrate ICT into the education system, support the education system with developments, improve it consistently by

assessing it and provide student-centered and project-based learning by using ICT" (Strategy Plan of MEB, 2010 – 2014). In the Strategy Plan of MEB 2010 – 2014, Strategic Goal 14.1 was stated as "to provide all schools with utilization of ICT in order to eliminate regional differences". Towards this aim, FATIH (The Increasing Opportunities and Improvement of Technology Movement) Project has been initiated. In this project it was aimed to provide tablets and interactive white boardsto all schools in preschool education, primary education and secondary education in Turkey. FATIH project has 5 components:

1. Providing Equipment and Software Substructure
2. Providing Educational e-content and Management of e-content
3. Effective Usage of ICT in Teaching Programmes
4. In-service Training of Teachers
5. Conscious, Reliable, Manageable and Measurable ICT Usage

Having a policy is a need for effective integration of technology as stated by Wachira and Keengwe (2010) and Cuban (2000). With FATIH project, Turkey will be able to remove many barriers on integration of technology stated in the literature such as unavailability of resources (Hardy, 2008; Wachira & Keengwe, 2010), lack of teacher training (Anthony & Clark, 2011; Strudler, N., Handler, M. G., & Falba, C. J., 1998), lack of teachers' experience (Becker, 2000; Cox et al., 1999; Fullan, 1991; Hadley & Sheingold, 1993), and lack of knowledge about how to use technological tools (Hardy, 2008; Wachira & Keengwe, 2010). These barriers (except unavailability of resources) cannot be solved without teachers' knowledge about integrating technology in education because three components of FATIH project; effective usage of ICT in teaching programs, in-service training of teachers, and

conscious, reliable, manageable and measurable ICT usage, require teachers' knowledge about using ICT in a real classroom setting effectively. Teachers' knowledge about using technology in education is an important component of technology integration in education according to related literature (Hardy, 2008; Wachira & Keengwe, 2010) and FATIH project in Turkey. Therefore it is important to have teachers who are knowledgeable about using technology in teaching process. Since in the near future, in Turkey all the classrooms will be equipped with interactive white boards, internet network, and tablet computers within FATIH project; teachers must have knowledge about teaching with technology. Therefore pre-service teachers are needed to have required knowledge to integrate technology into education when they graduate from teacher education programs. Teacher education programs have responsibility to train pre-service teachers as the ones who can use technology for educational purposes.

CHAPTER 2

LITERATURE REVIEW

Technology

Technology is defined in Canadian Encyclopedia (2014) as "the skills, tools and machines used by members of a society to convert material objects into products useful to themselves". This broad definition includes a great number of tools (e.g., Internet, printing press, telephone, industrial machines, and agricultural machines). In this study technology has a specific meaning. Technology means "educational technology, which describes the sum of the tools, techniques, and collective knowledge applicable to education. This definition includes both analog technologies (e.g., chalkboard, pencil, and microscope) and digital technologies (e.g., the computer, blogging, and Internet" (Koehler & Mishra, 2008, p.5).

Technology integration is a complex process. What makes technology integration complex are inherent characteristics of digital technologies and external barriers to technology integration as Koehler and Mishra (2008) stated. Inherent characteristics of digital technologies are being protean, unstable and opaque. Being protean means that digital technologies can be used many different ways. For example a computer has capability of storing and delivering visual, numerical and textual data. Or it can be used for communication, designing a web site and inquiry.

Therefore in technology integration process it is a necessity to select the ways by which a given technology will be used. Being opaque means digital technologies are not clear for users. For example users do not know about inner workings of a computer. There is a symbolic relation between computer and the user. It is a complex process for users how given technology works. Therefore it is not easy to solve technical problems for users. Being unstable means digital technologies change quickly. Therefore knowledge to learn a digital technology changes in a short amount of time. This makes learners' knowledge temporary. For example a teacher who uses educational technologies must follow improvements in technology which is required to be a life-long learner of technology. External characteristics that make technology integration complex are lack of teachers' experience with educational technologies, tension between technologists and educators (these two groups have different point of views in terms of technology), and diversity of classroom contexts. Therefore "there is not a definite solution to a technology integration problem" (Koehler & Mishra, 2008, p.11).

Teaching with technology is a wicked problem (Koehler & Mishra, 2008). This term describes a problem that does not have a definite solution (Rittel, 1972). There is not one rule to stop wicked problems (Rittel, 1972) and finding a solution to one aspect of a wicked problem may create other new problems (Koehler & Mishra, 2008). Koehler and Mishra (2008) stated that wicked problems occur in social contexts. Classroom is a social context with students, teachers and technology coordinators. Diversity of them causes technology integration to be a wicked problem and "the heart of good teaching with technology are three components; content, pedagogy, and technology and the relationships between them" (Koehler & Mishra, 2008, p.11).

Integration of Technology in Teacher Training

Teachers in today's classrooms must possess technological skills which enable them to use technological tools effectively. They can support their students' learning by using technological skills in classrooms. Programs of teacher education have responsibility to educate pre-service teachers as technologically skilled ones (Blankson, Keengwe, & Kyei-Blankson, 2010). However it is not an easy process to learn teaching with technology for pre-service teachers and it requires many efforts during their education (Angeli, 2005). This can be accomplished by having technology related courses in the curriculum of the teacher education program (Angeli, 2005; Blankson et al., 2010).

Having technology related courses in the curriculum makes technology available for pre-service teachers. Availability of technology for pre-service teachers during their education enriches their training. Pre-service teachers possess general technology literacy and technology literacy related to their content area. They have chances to practice more by using technology and using technology gives them chance to communicate in a group even if there is a distance among members of the group (Gomez, L., Sherin, M., Griesdon, J., & Finn, L., 2008). In a group, pre-service teachers not only communicate but also study collaboratively. In a technology related course, pre-service teachers support each other for using technology for educational purposes by collaborating within a group. In the literature importance of collaboration among pre-service teachers in a technology related course was emphasized (e.g., Blankson et al., 2010; Kay, 2007; Maeng, J. L., Mulvey, B. K., Smetana, L. K., & Bell, R. L., 2013; Özen, 2013).

One of the studies in which pre-service teachers worked collaboratively was done by Blankson et al. (2010). In this study all pre-service teachers are expected to be prepared to meet International Society for Technology in Education's (ISTE's) National Educational Technology Standards (NETS) and Performance Indicators (see Appendix A) for teachers. Blankson et al. (2010) design a pre-test post-test design research study in order to determine whether their technology class facilitated them to meet ISTE's NETS for teachers or not. They evaluated participants' perceived technological competencies by using a survey, focus group discussions, observations and portfolios. According to results of the study, participants obtained adequate content knowledge, technology experience and pedagogical skills. Using group work enabled participants to study collaboratively for class project and collaboration among them supported their understanding of the task. This course was included to create a website by using Microsoft Publisher. This part was interpreted as the most complex part of the course because they were challenged in creating a website. They faced with difficulties about technology by creating a website. Moreover it was reported that pre-service teachers had difficulty to install and uninstall a program. Blankson et al. (2010) noted that instructors of technology courses must give more opportunities to pre-services teachers to experience such easy technological skills during the course. Blankson et al. (2010) concluded that instructors must model appropriate technology integration practices during the course. Kay (2007) added that not only instructors of technology courses but also instructors of all courses are role models for pre-service teacher to use technology. There is an effect of their technology use on pre-service teachers' use of technology. Özen (2013) stated that there is a common usage of technology in courses by instructors and instructors' effective use of technology according to pre-service

teachers. However he indicated that there can be differences among faculties' facilities about ICTs. These differences may affect instructors' technology use.

Effective Technology Integration

In the literature, three key points for effective integration of technologies into classrooms were stated. They can be listed as;

- Availability of technological materials (Wachira & Keengwe, 2010)
- Technology related training (Becker, 2000; Strudler et al., 1998; Wachira & Keengwe, 2010).
- Systematic policy for technology integration (Cuban, 2000). These three points will be discussed in the following sections.

Availability of Technological Materials

Integration of technology in classrooms may be achieved by making proper hardware, software and Internet in classrooms. In other words technological tools are needed to be available in school. If not, teachers cannot experience a technological tool, plan instructional activities with that tool (Wachira & Keengwe, 2010).

Technology Related Training

Teachers are the most important factor in integration of technology in classrooms (Gorder, 2008). Therefore their professional development is important for technology integration process in classrooms (Gorder, 2008). Technology related training that develops teachers' attitude towards computers (Becker, 2000) is the point that is emphasized for effective integration of technology. Hardy (2008) focused on change in pedagogy of teachers in order to overcome barriers that prevent teachers to

integrate technology. This process needs support for teaching with technology that includes modification of instruction with technology. Therefore professional development of teachers is needed. Teachers learn technology integration within context of their classroom practices (Gorder, 2008). Lack of knowledge on how to integrate technology in classroom is a barrier resulting from lack of content-specific training. Meaningful mathematics activities should be used while developing the use of technology (Wachira & Keengwe, 2010). In technology integration process, teachers may be supported by teacher education programs, professional learning communities, mentoring and giving them context dependent strategies (Anthony & Clark, 2011). By this support, teachers come together, share ideas, and discuss issues on integrating technology (Gorder, 2008). According to Strudler et al. (1998), there is a need for adequate and careful training so that teachers become aware of possible benefits of information and communication technologies. Teachers who regularly participate in professional interactions and activities beyond their classrooms teach in different ways than teachers who have minimal contact with their peers and profession. They use computers for involvement in cognitively challenging tasks where computers are tools to promote communicating, thinking, producing and presenting ideas (Becker & Riel, 2000). “Best practices” of technology in content area integration and “excellent role models or technology integrators” are needed for teachers (Gorder, 2008, p.75). Hardy (2008) stated that activities should have practical values for teachers to integrate technology. They should give an effective model to teachers to use technological tool as instructional tool.

Systematic policy for technology integration

Integration of technology in classroom may be achieved by making proper hardware, software and enabling Internet access to classrooms, giving technical support to the teachers, encouragement of teachers by administration, helping teachers in their professional development in content specific instructional uses of technology (Wachira & Keengwe, 2010). All of those are related to having a national and institutional policy to integrate technology in classrooms. So lack of a systematic policy makes it difficult to use computers in classrooms (Cuban, 2000). For effective integration of technology, a policy related to technology is needed. School administration should support and encourage teachers to integrate technology in their classrooms.

Barriers for Technology Integration

There are some barriers for teachers which prevent them to integrate technological tools into teaching and learning processes. Unavailability of technology is one of those barriers. Technological tools need to be available in school. If not, teachers cannot experience technological tools, and plan instructional activities with these tools (Hardy, 2008; Wachira & Keengwe, 2010). Another barrier is lack of knowledge about using technological materials for educational aims (Anthony & Clark, 2011; Hardy, 2008; Wachira & Keengwe, 2010). Lack of technology support and technology leadership, anxiety and lack of confidence in using technology (Wachira & Keengwe, 2010), time constrains and financial constrains (Hardy, 2008), inadequate physical environment of classrooms (Anthony & Clark, 2011) are other obstacles for technology integration process stated in the literature. Even if these barriers are resolved, according to Fullan (1991), some teachers resist technology

integration process. However they do not reject the need for technology in education. They resist technology integration process because they are not given sufficient long-term opportunities to make sense of new technologies. Without long-term opportunities, teachers cannot experience with educational technologies and improve themselves. Experience and comfort with technologies is a factor that affects teachers' use of information and communication technologies (Hadley & Sheingold, 1993).

Differences in technology integration in terms of teachers' differences

Some of these teacher differences affect teachers in technology integration process. These are teachers' perceptions of learning and technology, experience of teachers in education and teachers' personal experiences with technology.

Successful integration of technology supports deep learning and encourages students to learn independently. Technology integration process is related to teachers' perceptions, approaches and learning contexts they provide (Cope & Ward, 2002). In Pass' (1998) study it was found that teachers' perception about learning is an important factor in successful integration of technology in education. For example, teachers who view learning as accumulation of information are more likely to view teaching as transfer of information. They use teacher centered instruction and they support students' rote learning by using technology. Teachers who perceive learning as conceptual change try to facilitate conceptual change. They encourage discussion and questioning among students (Prosser & Trigwell, 1999).

Experience of teachers is one of the factors that affect technology integration process. Experienced teachers who have more than 10 years teaching experience may

not facilitate their students for deep learning and conceptual change by using educational technologies. Experienced teachers may have limited professional development and inappropriate perception of educational technologies. Therefore it is not easy for them to integrate technologies in their classrooms and enhance learning outcomes (Cope & Ward, 2002).However, according to Thomas and Hong (2012); it may become possible for experienced teachers to use educational technologies if professional developments opportunities are given to them.

Personal experiences of teachers with technology have roles in teachers' self-confidence in classroom usage of technologies. Cox et al. (1999) claim that teachers who are already regular users of technologies such as computers in their daily life have confidence in using educational technologies in their classrooms.

Teacher knowledge

Before 1980, the most important qualification of a teacher was his/her subject matter knowledge. Methods and theories of teaching had a secondary role to test a teacher's quality. This view changed after 1980 (Ball, Thames, & Phelps, 2008). One of the perspectives about teacher knowledge is developed by Shulman (1986). Shulman (1986) distinguishes three categories of teacher knowledge; subject matter content knowledge, curricular knowledge, and pedagogical content knowledge. Subject matter content knowledge is the knowledge of subject and its organization in the mind of the teacher. Curricular knowledge is the knowledge of educational program and program materials for a given level. Pedagogical content knowledge includes

> The most regularly taught topics in one's subject area, the most useful forms of representations of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing and formulating the subject matter that make it comprehensible to others. (Shulman, 1986, p.9)

Shulman stated categories of teacher knowledge in a detailed way (1987, p. 8.). Those categories were;

- Content knowledge
- General pedagogical knowledge, with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter
- Curriculum knowledge, with particular grasp of the material and programs that serve as "tool of the trade" for teachers
- Pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding
- Knowledge of learners and their characteristics
- Knowledge of educational contexts, ranging from the workings of the group or classroom, the governance and financing of school districts, to the character of communities and cultures
- Knowledge of educational ends, purposes, and values, and their philosophical and historical grounds

Shulman (1987) underlined the importance of pedagogical content knowledge among those categories because it can distinguish a content specialist from a teacher. Shulman's idea of pedagogical content knowledge was referenced by many researchers in different areas such as engineering, mathematics, social studies, higher education, science, and others (Ballet al., 2008). Moreover researchers extended Shulman's idea of pedagogical content knowledge by adding technology domain to it. They built technological pedagogical content knowledge on technology framework on Shulman's idea of pedagogical content knowledge (Koehler & Mishra,

2009). Therefore the starting point of studies with TPACK framework is Shulman's Pedagogical Content Knowledge.

Technological pedagogical content knowledge (TPACK)

According to Gorder (2008) effective integration of technology is required ability of teachers to infuse technological tools into instruction that meets students' needs. According to Dockstader (1999), "integrating technology in the classrooms is a complex process that includes a) learning the technology, b) using technology in the teaching and learning process and c) integrating technology to enhance student learning" (as cited in Gorder, 2008, p. 64). "Teaching with technology is not simply adding technology to the existing teaching and content domain. True technology integration involves understanding and developing sensitivity to the dynamic, transactional relationship between three components of knowledge: technology, pedagogy and content" (Wachira & Keengwe, 2010, p.23).

Many educators of technology have the view that effective technology integration is not only affected by pedagogy but also it is dependent on the domain in which it is used. For example ways of using a technological tool is not same in a science classroom and in a mathematics classroom because they are different content areas (Graham et al., 2009). Integration of technology in classrooms was studied by different researchers with the framework of technological pedagogical content knowledge (TPACK) (Groth et al., 2009; Hofer & Swan, 2006; Koehler & Mishra, 2009). Shulman's study that included pedagogical content knowledge was used to build the framework of TPACK (Koehler & Mishra, 2009). TPACK is a powerful framework to study effective integration of technology into classrooms (Polly & Brantley-Dias, 2009). TPACK includes technology, pedagogy and content

knowledge. In this framework there are seven knowledge components stated as by Koehler and Mishra (2009).

Knowledge components of TPACK framework

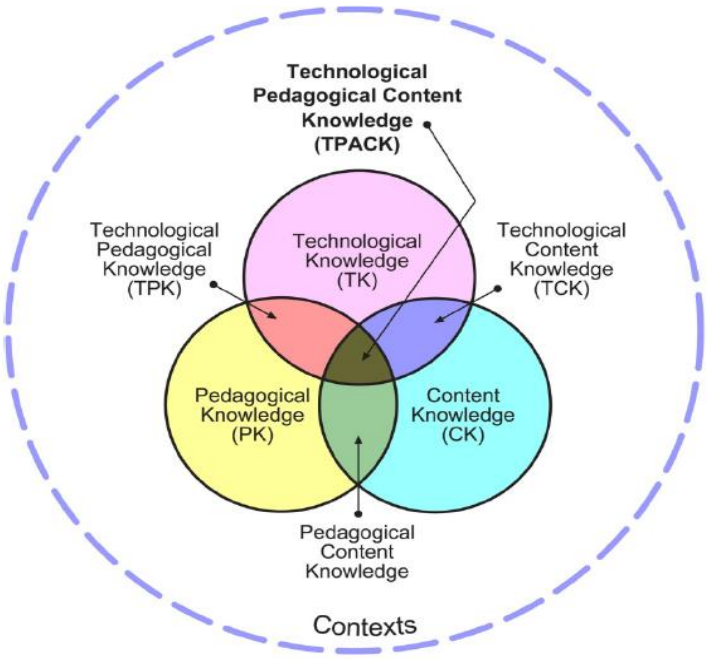


Figure 1: TPACK framework and its knowledge components (Koehler & Mishra, 2009).

In Figure 1, knowledge components of TPACK framework were given. As seen in the Figure 1, knowledge components of TPACK framework occurs by intersecting three knowledge components; technological knowledge, pedagogical knowledge and content knowledge.

In Figure 1 there are seven knowledge components of TPACK framework. These seven knowledge components were explained in detail by Koehler and Mishra (2009).

Teacher's knowledge about subject matter is defined as Content Knowledge (CK). For example mathematics' teachers' knowledge about theories, concepts, proofs and ideas in mathematics are related to mathematical CK. Without appropriate

CK, a teacher may harm students' development of knowledge of mathematics. Students learn incorrect information as if they are correct and they develop misconceptions in the content area.

Pedagogical Knowledge (PK) includes teachers' knowledge on teaching and learning skills. A teacher with PK has the knowledge of classroom management, assessment techniques, teaching methods, lesson planning, etc. Moreover a teacher with deep PK has knowledge about habits of mind and has ability to apply social, cognitive and developmental theories in leaning processes in the classroom.

Technology Knowledge (TK) can be defined as the knowledge of a teacher about technological tools and resources, using information technology. A teacher with TK uses technology in work and daily life. According to Graham et al. (2009), TK is a prerequisite for other forms of knowledge. Without basic skills of using technology it is not possible to integrate technology into teaching in a meaningful way.

Pedagogical Content Knowledge (PCK) is "transformation of subject matter for teaching" (Koehler & Mishra, 2009, p.64). The teacher uses appropriate teaching strategies, instructional planning, classroom management techniques and assessment techniques in teaching subject matter. Teacher with PCK is aware of common misconceptions, uses different teaching strategies for effective teaching.

Technological Content Knowledge (TCK) is knowledge of a teacher about the way by which technology and content are related. A teacher with TCK identifies the appropriate technological tools that can be used in teaching process of a subject matter. The selected technological tools support content area with multiple

representations. The teacher makes use of these tools and changes them when it is needed for a new subject matter.

Technological Pedagogical Knowledge (TPK) is the knowledge of effects of technology in teaching and learning processes and pedagogical strategies. For example, a whiteboard in a classroom is at the front of the classroom and students sit down in the direction of it. Teacher uses whiteboard to represent the topic to the classroom. However in a brainstorming part in the lesson all students may come in front of the whiteboard and write their ideas on the board. Therefore this technology may be used for different purposes in different ways. This is related to teacher's TPK. (Koehler & Mishra, 2009). Moreover a teacher with TPK is required to be creative and open-minded for technology use because much technological software such as Microsoft's Office Suite (Word, Excel, Msn, etc.) is developed for business not for education. Therefore teacher is the one who uses such software for educational purposes by using his/her TPK.

Technological Pedagogical Content Knowledge (TPACK) is an understanding that arises from three components; technology, pedagogy and content knowledge. TPACK is not simply addition of these three components. Interaction of them is required for formation of TPACK. Koehler & Mishra (2009) explained this idea as follows:

> 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)

This quote explains interactions among three components and it gives a role to the teachers in teaching with technology as stated by Gorder (2008). Koehler and Mishra (2009) explains teachers' role in technology integration process as flexible. There is not a single solution for teaching with technology for every classroom, every subject matter and every technology as stated by Koehler and Mishra (2008). Teachers are the ones who will produce special solutions for special contexts so Koehler and Mishra (2009) underlines pedagogical techniques of using technologies to teach content in constructive ways."The TPACK framework suggests that content, pedagogy, and technology have roles to play individually and together. Teaching successfully with technology requires continually creating, maintaining, and re-establishing a dynamic equilibrium between each component" (Koehler & Mishra, 2008, p.20). Therefore teaching with technology is a difficult work for a teacher to do well.

Studies in education with TPACK framework

Researchers used TPACK framework in their studies in different ways. Some researchers developed scales to measure TPACK and its knowledge components (e.g., Archambault & Barnett, 2010; Schmidt et al., 2009; Şahin, 2011; Yurdakul et al., 2012), some researchers focused on pre-service teachers' TPACK improvements with qualitative and mixed methods studies (e.g., Akkaya, 2009; Özmantar et al., 2010; Özgün-Koca et al., 2010; Timur, 2011) and other researchers preferred to study TPACK with teachers in their real classroom settings (e.g., Mouza, 2011; Polly, 2011).

Researchers tried to measure seven components of TPACK by using a scale or survey. Archambault and Barnett (2010) developed a survey for measurement of

TPACK of teachers. The aim was to measure each component of TPACK. Only component that distinguished itself was technology knowledge. By this survey, the researchers separated TK component of TPACK by asking questions on teachers' daily practices. The measurement instrument identified only technology domain. It did not identify pedagogical knowledge and content knowledge. The definition of content knowledge (e.g., mathematics, earth science, etc.) is an issue that makes it difficult to develop a survey because it restricts generalizability of the survey for different subject matters. Schmidt et al. (2009) developed Survey of Pre-service Teachers' Knowledge of Teaching and Technology. Data were collected from 124 participants from elementary or early childhood education. Therefore researchers designed the survey by considering participants' content areas (mathematics, literacy, science and social studies). However pre-service teachers from these departments teach in different content areas as mathematics, literature, science and social studies. As Schmidt et al. (2009) emphasized, future research is needed in measuring self-assessment of teachers in a specific content area such as a survey for content area of mathematics. In Turkey, Yurdakul et al. (2012) developed a scale to measure pre-service teachers' TPACK and Şahin (2011) developed a valid and reliable TPACK survey which was used in the current study. Researchers who developed surveys to measure TPACK emphasized the necessity of qualitative approaches within studies in TPACK researches. Archambault and Barnett (2010) argued that surveys cannot give observable data so it does not give accurate information as in observations. Polly and Brantley-Dias (2009) pointed out that teachers' TPACK is required to be analyzed during the classroom work instead of using a survey. Data must be collected in teachers' daily praxis by using observations, videotape recordings and classroom artifacts. Schmidt et al. (2009) added that they had a plan to observe those

pre-service teachers' classrooms to evaluate their level of TPACK. By this, they aimed at exploring "how scores on the TPACK instrument predicted classroom behaviors" (Schmidt et al., 2009, p. 137). Moreover Yurdakul et al. (2012) suggested that, based on items of the scales, a detailed and long term case study may be designed to measure pre-service teachers' TPACK development. They advised a research with both qualitative and quantitative methods. Therefore researchers, who designed surveys to measure TPACK, concluded the importance of qualitative methodology for measurement of TPACK. That's why both qualitative and quantitative methods were used in the current study.

Researchers who used qualitative methodology in TPACK studies directed participants to design an activity or a lesson plan by using technological materials. For example, Özgün-Koca et al. (2010) designed a qualitative study with 20 pre-service teachers within a secondary mathematics course in which students were required to design and implement "technology-rich teaching materials in the field setting" (p.10). In Akkaya's (2009) thesis, conducted as a part of a TUBITAK project named "Developing a program for pre-service mathematics teachers which aims to develop technological pedagogical content knowledge" (Akkoç, 2008), participants prepared a lesson plan and practiced microteachings about the concept of derivative. Another example in which concept of derivative is used came from Özmantar et al.'s (2010) study. They gave chances to the teacher candidates for planning and implementing micro teachings by using Graphic Calculus program that enabled them to use algebraic, numeric and graphical representations of derivative. Participants attended a course by which they learnt multiple representations. They also participated in a workshop to learn how to use the program of Graphic Calculator. Then they prepared their lesson plans and performed a microteaching. In

Özmantar et al.'s (2010) study pre-service teachers learnt using a program, and they designed teaching scenarios and showed their performance in microteaching. The findings of Özmantar et al.'s (2010) study showed that a technology course should include learning an educational program and practicing it in an environment such as microteaching. In the current study, such a technology course was selected to conduct the research. In a mixed methods study pre-service teachers' development of TPACK in force and movement subjects was analyzed by Timur (2011) in her PhD Thesis. She studied with 30 participants in a university course. Participants were given "the TPACK confidence scale" and "the microcomputer utilization in teaching efficacy beliefs instrument" (before and after the course). Then they attended a five weeks study which is designed for the aim of increasing technological knowledge. After five weeks, pre-service teachers designed a technology supported instruction and presented it in the course. Timur (2011) collected qualitative data from 3 of the participants via interview, observation and artifact examination. She found an increase in pre-service teachers' TPACK confidence and their self-efficacy beliefs towards computer utilization in science classrooms. She stated the course is effective for pre-service teachers' knowledge of curriculum and curriculum materials, knowledge of instructional strategies and knowledge of evaluation and assessment. In qualitative and mixed methods studies, pre-service teachers were given both theoretical knowledge about using program and chance of performing via program by designing technological materials, lesson plans and microteaching. These are the common characteristics of qualitative and mixed methods studies that used TPACK framework. Therefore in the current study these characteristics were considered in selection of the course in which the current study was conducted.

Some researchers designed studies in which participants were teachers (e.g., Mouza, 2011; Polly, 2011). In these studies teachers tried to integrate given technology in their teaching. For example, in Polly's (2011) study teachers used Google Documents and Wiki. Data were collected from qualitative data sources such as interviews and field notes were analyzed by using TPACK framework (e.g., Mouza, 2011; Polly, 2011). In Mouza's (2011) study teachers gained an increase in their TPACK, TK and TPK. In Polly's (2011) study teachers increased their TK. Polly (2011) and Mouza(2011) used TPACK framework to analyze their qualitative data. Their research questions were related to components of TPACK. Therefore they analyzed their data to determine components of TPACK.

In mathematics education Grandgenett (2008) stated ideas about integrating technology into mathematics teaching. According to Grandgenett (2008), educational technologies help teachers to prepare mathematical activities that are tied to computers. For example, creating a fractal is an activity that is done with the help of a computer program. As a famous example Sierpinski Triangle is given. It can be generated by a computer easily, for another example calculator may be given. For learning basic arithmetic, calculators can be used because they are good at doing calculations. However for a learner of basic arithmetic, using calculators may be inappropriate. At the point there are some questions to keep in mind for mathematics educators. First of all, what technologies will be used in classrooms? Secondly, how these technologies will be used to support classroom mathematics activities? An effective mathematics teacher is the one who is capable of deciding where technology fits in mathematics instruction. Having this capability requires three things. First of all a mathematics teacher must know the content in order to represent and appreciate mathematical contents deeply. Secondly a teacher must have

pedagogical knowledge to help students in the process of systematically building understanding of mathematics. Thirdly since technology has an important role in representation of mathematical contents (e.g., fractals) the teacher must use technology of mathematics in its instruction. First and second emphases of Grandgenett (2008) are related to many courses in a mathematics teacher education program. However the third emphasis about using technology in mathematics instruction is focus of the educational technology courses. In this technology integration process in mathematics education, it is possible for teacher education programs to provide teachers all potential TPACK (Grandgenett, 2008). Grandgenett (2008) gives a role to teacher education programs about giving all potential TPACK to pre-service teachers. This means that mathematics teachers must know how to use all potential technological tools and programs to teach mathematical contents to students. This requires using much educational program throughout pre-service teachers' education process. In many studies about TPACK framework participants used single program (e.g., Akkaya, 2009; Özmantar et al., 2010; Polly, 2011; Timur, 2011). Thus, the effects of courses where more than one educational program is introduced and expected from the students to be used would be worth investigating in a mathematics education setting. In the current study, pre-service teachers experienced three different educational programs related to mathematics.

Research questions

There are two research questions which guided this study.

1. Is there a difference between pre-service teachers' pre-test and post-test scores of components of TPACK framework in a computer assisted mathematics instruction course?

2. How do pre-service mathematics teachers' components of TPACK framework develop during the computer assisted mathematics instruction course?

CHAPTER 3

METHODOLOGY

In this section, research design, procedure of the study, participants, the setting of the participants, description of the course, data collection instruments and techniques, data collection and analysis procedures will be presented.

Research design

Mixed methods design is using both quantitative and qualitative methods in a single study to understand research problem (Creswell & Plano Clark, 2007). Mixed methods research has been used by researchers in recent years. The reason behind this choice is some advantages of mixed methods research. There are some strengths and weaknesses of quantitative and qualitative approaches. For instance, quantitative research provides numerical data to answer research questions that makes statistical comparison easily but its theories and categories cannot reflect all individuals' understandings because by numeric data it is not easy to capture feelings, ideas and viewpoints in a detailed way. On the other hand, qualitative research gives individual's personal experiences about phenomena and its results can be generalized to similar people and similar cases. Mixed methods research aims at benefitting from strengths of both quantitative and qualitative approaches and minimize weaknesses of quantitative and qualitative approaches (Johnson & Onwuegbuzie, 2004).

Mixed methods research is seen as third research community (Teddlie & Tashakkori, 2009) and third research paradigm in educational research (Johnson &

Onwuegbuzie, 2004). Being third means being a new research approach. Mixed methods research is used as an alternative to quantitative and qualitative approaches during the past 20 years (Teddlie & Tashakkori, 2009). Being an alternative does not mean to replace quantitative and qualitative approaches but rather to benefit from both (Johnson & Onwuegbuzie, 2004). Mixed methods research uses quantitative and qualitative approaches in various phases of research i.e., in problem statement, data collection and analysis procedures and inferences (Johnson et al., 2007). Mixed methods research combines quantitative and qualitative approaches to get a better understanding of research problems. Some research problems cannot be answered by one of the quantitative or qualitative research approaches alone. Mixed methods research provides an opportunity for researchers to answer those problems (Creswell & Plano Clark, 2007).

Educational researchers selected some classifications of mixed methods designs to conduct their researches. There are many classifications of mixed methods designs in the literature (e.g., Creswell & Plano Clark, 2007; Johnson & Onwuegbuzie, 2004; Teddlie & Tashakkori, 2009). The aim of the researcher is to select the most suitable type of mixed methods research design to get better answers to research question in this study. In the design of this study, the classification developed by Creswell and Plano Clark (2007) was used.

Creswell and Plano Clark (2007) stated four major types of mixed methods designs by explaining their aim, key points, strengths, weaknesses clearly and they emphasized on factors of timing, weighting, and mixing to select the most appropriate design. The four major types of mixed methods designs are;

a. Triangulation Design

b. Embedded Design

c. Explanatory Design

d. Exploratory Design

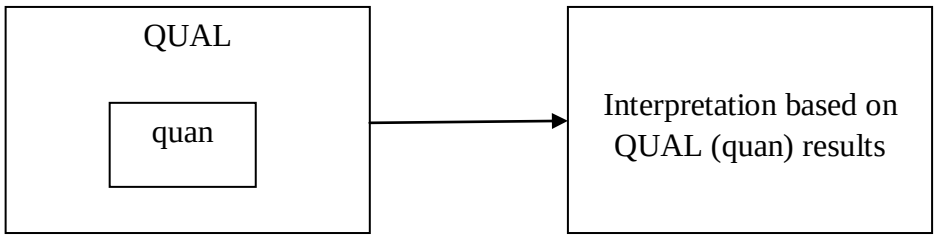
To decide on a mixed method design Creswell and Plano Clark (2007) stated a decision tree that includes criteria for timing, weighting and mixing (see Appendix B). For timing criterion, this research has concurrent timing. Each data was collected simultaneously. Therefore there is not a sequential timing among quantitative and qualitative data set. For weighting criterion, in this study there is unequal weight among two data sets. This study has qualitative emphasis. For mixing criterion, this study embedded the data. In this study quantitative data was embedded in qualitative design. Because of these criteria the nature of this study best fits in the embedded design to answer research questions in a better way.

The embedded design is a type of mixed methods design by which researchers use one data set to support other data set. Researchers can answer different research questions with the embedded design when each question needs different set of data. One of the data sets has a supplementary role in the embedded design (Creswell & Plano Clark, 2007). By adding the supplementary data, researchers have a chance to improve a larger design. Moreover researchers can save their time by giving less priority to one data set. Therefore the embedded design is a proper choice for researchers who do not have sufficient time. The embedded design is seen as a logical choice for graduate students because one of the methods has less data (Creswell & Plano Clark, 2007).

In this study both quantitative and qualitative data was collected but qualitative data set had a primary role and quantitative data set had a supplementary

role within the overall study. In Figure 2, the embedded design was shown. The reason of using upper cases in writing “QUAL” is qualitative data has a primary role in this study. The reason of using lower cases in writing “quan” is quantitative data has a secondary and supplementary role in this study. This study is a one-phase study and uses quantitative and qualitative data concurrently. Each data set was needed to answer two different research questions of this study. Quantitative data was collected at the beginning and end of the study with a quantitative data collection instrument (i.e., a scale) to answer research question 1. Qualitative data was collected with qualitative data instruments (i.e., interviews and observation) to answer research question 2 throughout the study.

Figure 2. The Embedded Design

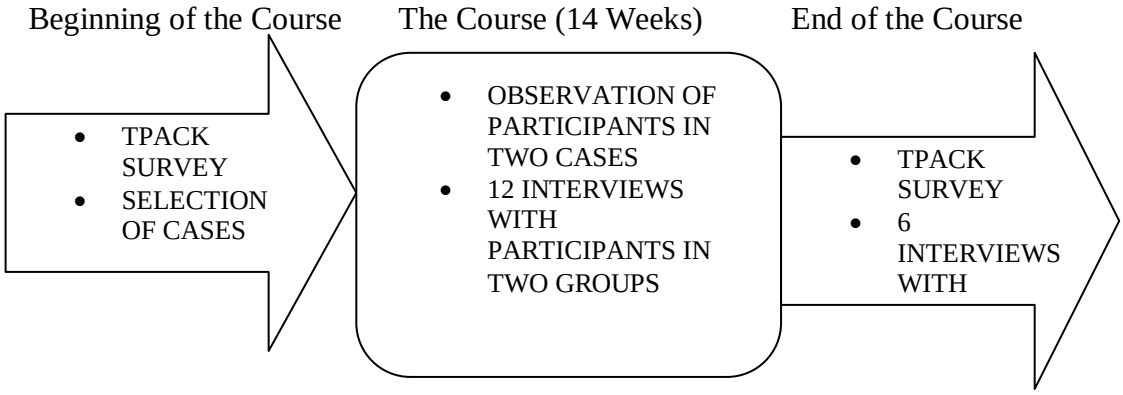


Procedure of the study

In this study 29 pre-service mathematics teachers completed TPACK survey at the beginning of the computer assisted mathematics instruction course. Then six of them were selected as participants of qualitative part of this study according to TPACK Survey scores. Namely there were two cases in qualitative part; members in one case were heterogeneous, members in the other case are homogeneous according to their TPACK scores. Then these two cases were observed in the course by the researcher. Three semistructured interviews for each participant were conducted. At

the end of the course TPACK Survey was completed by all participants as post test. In Figure 3, procedure of the study was schematized.

Figure 3. Procedure of the Study



Participants

In this study participants were selected purposefully. A last year course in a university was selected as the context of the study. The name of the course is "Computer Assisted Mathematics Teaching". The reason of this selection is the suitability of the course with aim of this research. This aim of the study is exploring pre-service mathematics teachers' TPACK development. The course's aim is increasing pre-service mathematics teachers' awareness in using available technologies in teaching mathematics as stated in the syllabus of the course. The two aims are highly relevant.

The course was taken by 31 pre-service mathematics teachers. 29 of them attended the course throughout the semester. 6 of them were male and 23 of them were female. Their ages ranged from 21 to 28. At the beginning the course all pre-service mathematics teachers were informed by the researcher about the aim of the

research. They accepted to participate in the quantitative part of the study voluntarily. These 29 pre-service teachers completed a survey.

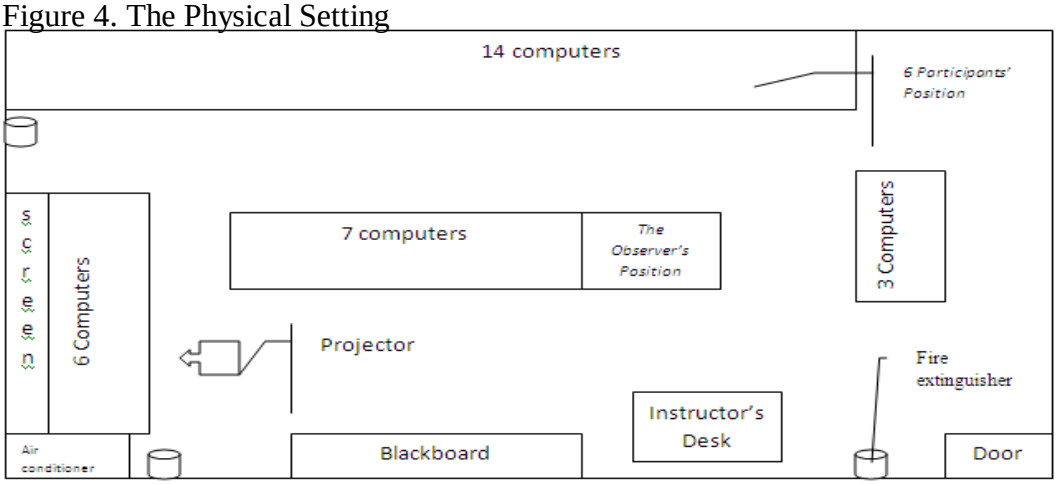
For the qualitative part of the study 6 participants were selected purposefully. Creswell and Plano Clark (2007) stated two approaches in purposeful sampling. One of them is maximal variation sampling in which participants have different characteristics (e.g., gender, academic success, and race) or different perspectives on a phenomenon. The aim of maximal variation sampling is providing a better qualitative study by gathering different views from different participants. Other approach of purposeful sampling is homogenous sampling in which participants have similar characteristics (e.g., gender, academic success, and race) or similar perspectives on a phenomenon. In this study by using the results of pre-service teachers' TPACK survey three groups (9 participants) were identified by me as the researcher and with the advice of my thesis advisor and course instructor (suggestions to select individuals who can willingly contribute to the research) two groups were selected. In this study, these two groups are taken as two cases. One of these groups was selected by using approach of maximal variation sampling according to their TPACK survey scores. The other one was selected by using approach of homogenous sampling according to their TPACK survey scores. The participants' TPACK survey scores will be presented in the results part.

The physical setting of participants

The physical setting was a university computer laboratory that includes 30 desktop computers with headsets, approximately 40 chairs with wheels, and a desk for instructor, one projector, a white screen on the wall for projector, a blackboard, an air conditioner, and three fire extinguishers. Moreover the setting is well lighted with 9

windows. Only one of the computers did not work during the semester but this did not create a problem. There were 29 pre-service teachers taking the course. Therefore in each computer one pre-service teacher studied. Since chairs had wheels, pre-service teachers could move around and change their position in the course easily. If they needed to ask their friends, they could go near their friends with the chair and study with them in a one computer. The physical plan of the setting is presented in the Figure 4.

Figure 4. The Physical Setting



Description of the course

In this study participants were students taking course named as "Computer Assisted Mathematics Teaching" in a university. The aim of the course aim is to increase awareness of pre-service mathematics teachers' towards using available technologies in teaching mathematics as stated in the syllabus of the course. In this course, pre-service mathematics teachers learnt how to use new programs in teaching mathematics. In the first three classes, the instructor presented properties of Interactive White Boards (IWB) and pre-service mathematics teachers

practiced with IWBs. Educational programs pre-service mathematics teachers studied during the semester were; GeoGebra, Tinkerplots and Cabri 3D.

GeoGebra is dynamic mathematics program that can be used in geometry, algebra and statistics. Geogebra can be freely downloaded from www.geogebra.org/csm/download. In this course generally geometry applications of GeoGebra were presented by the instructor. Tinkerplots is a dynamic program that enables students to enter data, draw graphic and study probability. Tinkerplots cannot be used freely. In this course, instructor presented how to manage data, use data to make statistical calculations and do probability calculations. Cabri 3D is a dynamic program for three dimensional geometry. Cabri 3D can be downloaded from www.cabri.com/download-cabri-3d.html. In this course, the instructor presented basic properties of the program, construction of 3 dimensional objects and calculations on 3 dimensional objects.

The course started in 24 September 2012 and ended in 26 December 2012. In Table 1, the timeline of the course is presented. As seen in the Table 1, the course lasted for14 weeks. In each week, classes were given on Tuesday and Thursday. In each of these two days, pre-service mathematics teachers attended the course during two hours.

In the process of the course each educational program was studied in the same manner. Firstly new program was introduced to pre-service mathematics teachers by the instructor of the course. The instructor of the course used some applications that were done by pre-service mathematics teachers, while he was introducing new program. Therefore pre-service mathematics teachers actively engaged in applications in the course. Then pre-service mathematics teachers studied for

their presentation of new program with the support of the instructor. In this part, pre-service mathematics teachers studied with their groups.

Table1.*Computer Assisted Mathematics Teaching Course Timeline*

	DATE	TASK
1. Week	24 Sept - 30 Sept	IWB
2. Week	01 Oct - 07 Oct	IWB –GeoGebra
3. Week	08 Oct - 14 Oct	IWB practice – GeoGebra
4. Week	15 Oct - 21 Oct	GeoGebra
5. Week	22 Oct - 28 Oct	GeoGebra Presentation Preparation
6. Week	29 Oct - 04 Nov	GeoGebra Presentation Preparation – Tinkerplots
7. Week	05 Nov - 11 Nov	Geogebra Presentations
8. Week	12 Nov - 18 Nov	Tinkerplots
9. Week	19 Nov - 25 Nov	Tinkerplots Presentation Preparation
10. Week	26 Nov - 02 Dec	Tinkerplots Presentation Preparation - Tinkerplots Presentations
11. Week	03 Nov - 09 Dec	Tinkerplots Presentations -Cabri 3D
12. Week	10 Nov - 16 Dec	Cabri 3D
13. Week	17 Nov - 23 Dec	Cabri 3D Presentation Preparation - Cabri 3D Presentation
14. Week	24 Nov - 26 Dec	Cabri 3D Presentation

In the presentation, pre-service mathematics teachers were free to choose their way of presentation. They could make a micro-teaching by using program, they could present a 40 minutes lesson plan of using program in a mathematics classroom, or they could just construct something by using program. In the last part, pre-service mathematics teachers presented their studies. After each presentation, the instructor and pre-service mathematics teachers discussed the presentation and shared their ideas and comments.

Data collection instruments

In this study quantitative data were collected by using pre-service teachers' TPACK Survey developed by Şahin (2011). Qualitative data were collected by using semi-structured interviews and observation.

Quantitative data collection instrument

In this study TPACK Survey developed by Şahin (2011) was used as the quantitative data collection instrument. TPACK Survey is a 47-item Likert-type scale with 5 choices. These choices include "1=not at all," "2=little," "3=moderate," "4=quite," and "5=complete." Minimum score that can be taken from TPACK Survey is 47. Maximum score that can be taken from TPACK Survey is 235. TPACK Survey includes 7 subscales of TPACK model:

Table 2. *Subscales of TPACK Survey*

subscale	number of items
PK	6
CK	6
TK	15
PCK	7
TPK	4
TCK	4
TPACK	5

In Appendix C, items of TPACK Survey were given by getting permission from Şahin. Below are some samples from items of TPACK Survey.

I know how to solve a technical problem of a computer (TK)

I know how to evaluate suitability of a new technology for teaching and learning (TPK)

I know suitable technologies for my content area (TCK)

I know how to integrate suitable technologies and teaching methods and strategies with content area (TPACK)

TPACK survey was a reliable and valid instrument according to findings of Şahin (2011). In Şahin's (2011) study firstly, reliability and validity study was conducted with 348 pre-service teachers. The construct validity of the survey was provided using exploratory factor analysis. Then, it was determined that the TPACK survey has six (TK, PK, CK, TPK, TCK and PCK) distinct factors with their eigenvalues higher than 3.00. In addition, it was found that there was a statistically significant correlation between subscales.

As for the reliability of TPACK survey, Cronbach's alpha coefficient was calculated. The internal consistency scores for each subscale were calculated as follow: 0.93 for TK, 0.90 for PK, 0.86 for CK, 0.88 for TPK, 0.88 for TCK, 0.92 for PCK, and 0.92 for TPACK. The results showed that the subscales had reliable because the scores are higher than 0.70 (Creswell, 2012). In addition, item-total correlations were calculated. The scores were ranging from 0.62 to 0.90, which indicate a highly positive and strong relationship among all of the subscales.

Şahin (2011) also provided discriminant validity for TPACK survey. To test discriminant validity of TPACK Survey, 205 pre-service teachers were studied. Participants' grades in related classes (i.e., area classes, pedagogy classes, technology classes) were used to test criterion-related validity. Şahin (2011) reported

that there were correlations between related grades and subscales of TPACK Survey, with higher significant level.

Şahin (2011) provided with evidence of test-retest reliability of TPACK Survey. He studied with 76 pre-service teachers. TPACK Survey was answered two times by participants in three weeks. The reliability coefficient was determined as 0.80 ($p < 0.01$) for the TK subscale, 0.82 ($p < 0.01$) for the PK subscale, 0.79 ($p < 0.01$) for the CK subscale, 0.77 ($p < 0.01$) for the TPK subscale, 0.79 ($p < 0.01$) for the TCK subscale, 0.84 ($p < 0.01$) for the PCK subscale, and 0.86 ($p < 0.01$) for the TPACK subscale. Overall, these results confirmed the test-retest reliability of the survey.

Qualitative data collection techniques

In this study observation and interviewing were used as qualitative data techniques. Observation defined by Creswell (2012) as gathering firsthand information by observing people in a research setting. By observing people it becomes possible to gather information about behavior as it is happening (Merriam, 2009). The reason of choosing observation as a data collection instrument is gathering information about actual behavior of participants in the setting. By observation researchers can make drawings of the setting and take field notes about events and activities in the setting (Creswell, 2012), specific incidents in the setting and behaviors of participants (Merriam, 2009).

In this study observation was used as a qualitative data collection form. Observation was done in the setting of "Computer Assisted Mathematics Teaching" course during the semester (14 weeks). In the first week of the course, I as the

researcher, entered the setting and informed 29 pre-service teachers about the study's aim and process of the study. After getting their permission, observation process started. The role of the researcher can be described as the nonparticipant observer (Creswell, 2012). Being a nonparticipant observer (Creswell, 2012) does not affect the events in the setting and participants may feel more comfortable in their setting (Creswell, 2012). In this study, during the observation process the researcher just visited the setting and he did not participate in activities. The researcher acted as an outsider by not involving in activities in the setting. The researcher's aim was to watch and record the events and activities that could enable the researcher to understand phenomenon with firsthand data.

During the observation, the researcher sat at a place that was suitable to see two groups (6 participants of qualitative part of the study) and the position of the researcher did not affect participants. The researcher was positioned back of the participants and he did not close their views in the computer laboratory. The main focus of the researcher's observation was those 6 participants but the researcher also observed other people and events in the setting from time to time in order to get data about whole setting. The researcher took both descriptive and reflective field notes. In descriptive field notes as stated in the literature (Creswell, 2012), the researcher tried to described events, activities and people in the setting. In reflective field notes as stated in the literature (Creswell, 2012), the researcher tried to record his own thoughts and ideas about situations and people in the setting.

Interviewing is the most commonly used data collection technique in qualitative research (Creswell, 2012; Merriam, 2009). Interviewing with a participant means asking open-ended questions, recording answers and transcribing the dialogue

with the participant to a computer file for analysis (Creswell, 2012). Interviewing is generally a person-to-person interaction between participant and researcher (Merriam, 2009).

In the literature three types of interviewing structures are stated; highly structured, semistructured and unstructured (Merriam, 2009). In this study semistructured interviews were used to collect data via interviewing. In semistructured interviews open-ended questions are used without a predetermined order. Researcher uses interview questions flexibly. There is not an exact order of asking question. According to participants' responses, researcher can change the flow of interview questions. Researcher asks new questions that are not in interview questions list. This type of interviewing structure makes getting new ideas of participants on the topic possible (Merriam, 2009).

In this study I as the researcher tried to follow these hints to collect required data that would enable me to learn about participants' perspectives. I spoke less than the participants and avoided being directive. My aim in an interview was to learn from the participant about questions related to research study.

In this study three interviews were conducted with each of the 6 participants. In these three interviews generally parallel questions were used. In these three interviews open-ended questions were generally related to participants' general views on technology, their views on technology in a primary education mathematics class, their views on the course, their learning process in the course, their relations among group, their views on program (i.e., GeoGebra, Tinkerplots, Cabri 3D) studied in the course. The research questions were prepared by me then they were checked by the advisor of the thesis. Research questions were organized again by

taking account of the advisor's comments. The research questions that were used in these three interviews were given in Appendix D.

Three semistructured interviews were conducted with all participants. First interviews were conducted in the first weeks of the course, second interviews were conducted in the middle of the course, and the last interviews were conducted after course was ended. Dates of interviews were presented in Table 3. Participants' pseudo names were given in Table 3.

Table 3. *Interview Dates*

participant	interview 1	interview 2	interview 3
Emine	9 October	03 December	4 March
Zeynep	16 October	06 December	25 February
Berk	11 October	15 December	2 March
Meryem	9 October	07 December	28 February
Aslı	18 October	04 December	20 February
Ece	15 October	11 December	1 March

In qualitative methodology the terms of trustworthiness and credibility are used instead of reliability and validity (Merriam, 2012). In this study issues of trustworthiness and credibility were considered. First of all, for triangulation, data was collected through different data sources; interviewing and observation. Secondly, participants and the context of the course were explained in a detailed way in order to generalize the results of the study for similar cases and the results were presented with their evidences to ensure transferability. Thirdly in data analysis process, peer review was done. Coding process of this study was maintained under consultation of an expert. Data coming from interviews and observations discussed with an expert.

Analysis of Data

To analyze quantitative data, The Statistical Package for the Social Sciences (SPSS, 2009) program was used. The aim of quantitative data analysis was to answer research question 1. Since the number of pre-service mathematics teachers taken the course is lower than 30, a non-parametric test was used in analysis of quantitative data. By using Wilcoxon test, whether there is a statistically significant difference between pre-test and post-test scores of pre-service mathematics teachers or not was analyzed.

In this study, qualitative data were collected through interviewing and observation. Qualitative data coming from interviewing was in the format of audio recording, so it was transcribed into computer file by the researcher. Qualitative data coming from observing were written text, therefore it was not written again as a computer file.

There are many qualitative data analysis software. Qualitative data analysis software is used to store, organize, and code data. In this study MAXQDA was used in analyzing process of qualitative data. By using MAXQDA raw data of 141 pages were organized and analyzed (see Appendix E).

Analyzing qualitative data as Creswell (2012) refers there is not only one way. In this study, Creswell (2012)'s procedure was used with one difference. In Creswell (2012)'s procedure there are six steps:

1. Reading all transcripts carefully
2. Pick one document and ask yourself "what is this person talking about?"
3. Begin process of coding

4. Group similar codes and reduce number of codes
5. Go back data, and check new codes emerge or not
6. Reduce list of codes get five or seven categories (themes)

In this study, these steps were used with one exception. In step 3, Creswell (2012) recommends to use line coding in which a small number of codes are used. For example for 20 pages 10 or 15 codes are used. In this study open coding was used in order to be open to anything possible at this point (Merriam, 2009). Any part of the data could be important. Therefore open coding used in step 3. This is resulted in many codes at the beginning of the coding process. Then the list of open codes was by grouping them. New codes were checked in the data. At the last step, categories with subcategories were formed. Field notes coming from observations were analyzed with the same way but they did not transcribed into the computer file. Since data coming from field notes were in written form, the analysis process of field notes were maintained by hand.

CHAPTER 4

RESULTS

In this section results of data analysis will be presented. Firstly results of quantitative data analysis will we presented to answer research question one. Secondly results of qualitative data analysis will be presented to answer research question two.

Results of quantitative data analysis

Quantitative data were collected through TPACK Survey (Şahin, 2011) to answer research question one that is stated below. Data collected from 29 pre-service mathematics teachers were analyzed by using Wilcoxon Singed Ranks Test. The aim of using Wilcoxon Singed Ranks Test is analyzing whether there is a significant difference between pre and post-test scores of the sample.

Research Question 1: Is there a difference between pre-service teachers' pre-test and post-test scores of components of TPACK framework in a computer assisted mathematics instruction course?

Null Hypothesis (H_0): There is no difference between pre-service teachers' pre-test and post-test scores of components of TPACK framework in a computer assisted mathematics instruction course.

Alternative Hypothesis (H_1): There is a difference between pre-service teachers' pre-test and post-test scores of components of TPACK framework in a computer assisted mathematics instruction course.

In table 4, it is seen that there is an increase between pre-test and post-test scores of 25 participants, there is a decrease in pre-test and post-test scores of three participants, and there is one participant whose pre-test and post-test scores are equal. In Table 4, it is stated that there is a significant difference between pre-test and post-test scores (p<,05). Therefore null hypothesis is rejected and alternative hypothesis is accepted. According to results of this study there is a significant difference between pre-test and post-test scores of pre-service mathematics teachers' TPACK scores. Although there is not a control group in this study, it can be concluded that participants' TPACK development was affected by the course because the computer assisted mathematics instruction course is the only course related to technology that pre-service mathematics teachers taken in the term. When we look at mean scores of pre-test and post-test in table 5, it is seen that there is an increase in post-test scores compared to pre-test scores. Table 6 is presented to investigate the difference between pre-test and post-test scores of subscales of TPACK Survey.

Table 4.*The Difference Between Pre and Post Test Scores of the Sample in TPACK Survey that is Analyzed by Wilcoxon Signed Ranks Test*

Groups	*N*	X	∑	*Z*	*p*
Decreasing	3	11,33	34		
Increasing	25	14,88	372	-3,84	,00
Equal	1				
Total	29				

Table 5.*The Difference Between Pre and Post Scores in Total Scores of TPACK Survey that is Analyzed by Wilcoxon Signed Ranks Test*

TPACK Total	N	X	SD	Min	Max
Pre_Test Total	29	155,10	21,24	111	208
Post_Test Total	29	174,41	19,31	126	215

Table 6.The Difference between pre and post scores in subscales of TPACK

Subsclales	N	X	SD	*p*	*Z*
Pre_PK	29	18,79	3,83		
				0,001	-3,38
Post_PK	29	21,27	3,05		
Pre_CK	29	18,41	2,70		
				0,003	-2,95
Post_CK	29	20,55	2,55		
Pre_TK	29	53,34	9,03		
				0,011	-2,53
Post_TK	29	56,68	8,13		
Pre_PCK	29	23,86	3,61		
				0,004	-2,86
Post_PCK	29	26,62	3,29		
Pre_TPK	29	12,86	2,06		
				0,001	-3,23
Post_TPK	29	14,93	2,01		
Pre_TCK	29	12,41	2,35		
				0	-3,66
Post_TCK	29	15,37	1,98		
Pre_TPACK	29	15,41	3,25		
				0	-3,64
Post_TPACK	29	18,96	2,87		

In Table 6 it is seen that there are significant differences between pre-test and post-test results in subscales of TPACK; PK ($p<,05$), CK ($p<,05$), TK ($p<,05$), PCK ($p<,05$), TPK ($p<,05$), TCK ($p<,05$)., and TPACK ($p<,05$). According to results there is an effect of the computer assisted mathematics instruction course on participants' scores on TPACK's subscales. When we look at mean scores of pre-test and post-test in table 6, it is seen that there is an increase in post-test scores according to pre-test scores for all subscales of TPACK.

In Table 7 participants' pre-test and post-test TPACK scores were given. According to results of participants of Group A (Emine, Zeynep, and Berk), their TPACK scores are heterogeneous in pre-test. In Table 7, it is seen that, Zeynep and Berk's TPACK scores increased from pre-test to post-test, whereas there is a

decrease in Emine's TPACK score from pre-test to post-test. Moreover Zeynep has the lowest TPACK score in both pre-test and post-test among all participants. For Group B (Meryem, Aslı, and Ece) their TPACK scores are homogeneous in pre-test. In Table 7, it is seen that, all participants TPACK scores increased from pre-test to post-test in Group B.

Table 7.Participants' pre-test and post-test TPACK scores

Participant	Pre-test	Post-test
Emine	208	189
Zeynep	111	144
Berk	172	208
Meryem	155	207
Aslı	140	179
Ece	149	206

Results of qualitative data analysis

In this study qualitative data were collected through semistructured interviews and observations in order to answer the second research question. In this section, qualitative results will be presented. In the qualitative part of this study, there were six participants in two groups. The results of qualitative data will be presented for these two groups: Group A and Group B.

Information about participants of Group A

In this section firstly I will introduce members of Group A, then I will present results coming from Group A's interviews and observation with respect to themes, categories, and subcategories.

In Group A, there are three participants. Their TPACK scores in the pre-test are dissimilar to each other. Namely Group A is a heterogeneous case in terms of participants' TPACK scores.

Emine is a senior pre-service mathematics teacher. She is a prolonged pre-service teacher. She was registered in the program 9 years ago. She is in her eight term in university. She is 28 years old. She is working in a private educational institution. She states that she does not have personal interest in technology.

'…I cannot say that technology is in my personal interests, I understand from technology. I know about technology as I need' (Emine, Interview 1)

Emine uses technology for communication and entertainment in her personal life.

'My students generally use Blacberry because of ease of BBM. To communicate with my students I changed my phone with a Blackberry…' (Emine, Interview 1)

'I use my notebook to watch TV series and I use facebook and tweeter…' (Emine, Interview 1)

Zeynep is a senior pre-service mathematics teacher. She is in her seventh term. She is 22 years old. She does not have personal experience in teaching. Namely, she does not work in an educational institution. She thinks that she is not a skillful person in technological issues.

'I am not interested in technology, and I do not have effort for technology…' (Zeynep, Interview 1)

'I am not skilled but I do not deal with technology…' (Zeynep, Interview 1)

Zeynep uses her personal computer for watching movies, reading newspapers, using facebook, and using some of Microsoft Office programs.

Berk is a senior pre-service mathematics teacher. He is in his eight term in university. He is 26 years old. He is working in a private institution. He states that he has personal interest in technology and he thinks that he has capability to use computers.

'I am good at using computers…' (Berk, Interview 1)

'Whatever I need in computer, I learn it and I use it…' (Berk, Interview 1)

Berk uses his personal computer to learn what he is curious about.

'…If I need something, I use computer to find and learn it…' (Berk, Interview 1)

In the following section, I will present results of Group A under four themes. These themes are technology theme, personal factors theme, group work theme, and structure of the course theme.

Group A's results under Technology Theme

Under technology theme, there are two categories: Technology overview and Technology in education. Category of technology in education includes two subcategories: Technology in teaching and Technology in learning. I will present each of them one by one. In Table 8, there is a representation Technology Theme.

Table 8. Technology Theme

TECHNOLOGY THEME
Technology Overview
Technology in Education
Technology in Teaching Process
Technology in Learning Process

Technology overview was a category that has a role on participants' development in components of TPACK framework during the course. Results of Group A showed that participants' technology overview may have a role on their learning process in the course. In the interviews, technology overview of the participants in Group A gave their perspectives on technology. In Group A, Berk and Zeynep saw technology as an essential part of today's life. Emine's technology

overview was different from her group members'. Her technology overview changed during the course. At the beginning, she viewed technology as a male dominant domain. She thought that "males are better than females in technological issues" (Emine, Interview 1). Males were more knowledgeable then girls according to Emine. Emine was working in a private institution and she did not need technology in her workspace. Therefore at the beginning of the course she saw technology as a luxury, and she implied that she did not need it.

> 'I can do without technology. Things can be better with it but using technology is a luxury. Things can be without technology' (Emine, Interview 1)
>
> 'I do not need technology now. This is a practice issue I guess. I can use in the future…' (Emine, Interview 2)

In the last interview she talked about technology as an interesting issue that could be used by her. Her technology overview changed throughout the course. At the beginning and in the process of the course she did not state positive overviews about technology but at the end of the course she stated positive overviews about technology.

> 'Technology is an interesting issue. It is something that is used very easy but if you do not know, you can do nothing. I cannot tolerate being in such a situation. At least, I can develop something and use it' (Emine, Interview 3)

Emine's technology overview reflected the issue about using technology necessitating appropriate knowledge. She underlined importance of TK to develop a product with technology and use it.

Technology in Education was another category of Technology Theme. Their perceptions of Technology in Education had an effect on their learning in the course. They were aware of the importance of Technology in Education. I will report results

of Technology in Education in two subcategories; Technology in Teaching Process and Technology in Learning Process.

Zeynep and Berk had a view on technology in teaching process, whereas Emine did not give a role to technology in teaching process. She implied that technology is not an essential part of teaching process. However in Zeynep and Berk were aware of potential benefits of technology when they become teachers. According to results of Group A, Zeynep and Berk thought technology as a part of a classroom and they developed their TPACK by assigning some roles to technology in teaching process. They were aware of having limited time in the classroom. In Group A, Berk stated about the role of technology for saving time in a classroom. He thought saving time in a technology integrated classroom environment occurs in two ways. First of all in a technology integrated classroom environment, teachers do not make many repetitions because students see things easily. Secondly making drawings especially in geometry classes takes much time. Teachers can draw geometrical objects fast by using technology. As a specific example of this point the following comment can be considered: "IWBs are chances for teachers. With IWBs, teachers can take attention of students in one point but in black board drawings take much time" (Berk, Interview 2). Teachers make progress without consuming much time for drawings. Berk stated saving time as a potential benefit of using technology in classroom and he explained how using technology saves time in a real classroom setting. Namely he related technology with some pedagogical issues such as students' learning easily and teachers' taking attention of students. These were the signs of having TPK for Berk.

Manipulation was stated by Berk and Zeynep in interviews as a role of technology in teaching process. They indicated that teachers and students had a

chance to change things in educational programs which made their work easy. They implied importance of manipulating objects in geometry. “For example let’s think on cube or pyramid. Educational program is valuable to teach properties of them. I can move things on them easily and I can make measurements on them...” (Zeynep, Interview 3). In this quote it was seen that Zeynep was aware of using technology for teaching three dimensional objects. She explained using manipulation property of technology in specific mathematical contents such as cubes and pyramids. This can be considered as a manifestation of her development of TCK. By using manipulation property of technology, a teacher makes things easier in teaching process. Berk mentioned importance of manipulation. He stated that teaching and learning were easier by manipulating objects and observing changes in those objects.

> ‘At this point importance of manipulation is seen. I can give 50 triangles on a paper. Some of them denote a triangle some of them do not. I can say the relation among lengths of edges but if a student changes lengths of edges and observe whether a triangle is formed or not, s/he can clearly recognize the relation among lengths of edges’ (Berk, Interivew 1).

These sentences were related to Berk’s TPACK because he shared his ideas about manipulation property of technology by relating technology with a mathematical content and students’ learning.

All participants thought that integrating technology in a real classroom setting may change teacher’s role. Therefore when they become teachers, if they use technology, they suppose a different role in a technology integrated classroom than a classic classroom environment. Interestingly all participants gave the same role to teachers in a technology integrated classroom environment. The role of a guide was given to the teacher in such a classroom environment. The idea of Berk about the role of the teacher in a classic classroom environment was interesting. “In a classic classroom environment teacher’s role is telling and teaching (Berk, Interview 1). In a

technology integrated classroom environment "the most important role of a teacher is guidance" (Berk, Interview 1). Being a guide was the role of the teacher in a technology integrated classroom environment. Zeynep explained the background of this opinion: Although students know how to use educational programs, they will get confused and stop studying. Therefore teachers must guide them not to get confused with educational programs. I concluded that participants of Group A gave a new role to the teacher in a technology integrated classroom environment and this was related to their TPK development throughout the course.

In the teaching process, participants shared their ideas on using technology in a real classroom setting. In this group Berk had ideas on how to benefit from learned educational programs in real classroom setting. Berk mentioned, "Tinkerplots can be used for a short activity such as one lasting for 15 minutes. If it becomes more it can be perceived as a game by students. For Geogebra a 40 minute class should be designed" (Berk, Interview 2). Emine stated that she did not have an idea on this issue. Namely she did not know how to use educational programs in a real classroom.

> 'I not sure that how I can use my learning with educational programs in a real classroom…' (Emine, Interview 1)

The reason behind her idea could be her lack of experience with technology in a real classroom setting as she implies:

> 'I think I can use technology but I am not sure because I did not teach in a technology integrated classroom before…' (Emine, Interview 2)

Although Berk and Emine worked in private institutions, Berk had an idea of using technology in a real classroom setting but Emine did not. This difference occurred from Berk's personal interest in technology and personal effort to use technology in his workspace. In the interviews he stated that he used educational programs in his

classes therefore he developed an idea about using technology in a real classroom setting throughout the course. I concluded that Berk's TPACK development occurred by merging his experience from the course with his past teaching experience and thinking about educational programs in real classroom settings.

According to interviews' results, Zeynep and Berk related mathematics with technology. They gave a role to technology in mathematics and they linked mathematical content with technology. Namely they developed their TCK throughout the course. Zeynep gave an example about probability and Tinkerplots's role in teaching probability.

> '…I think that probability is a difficult topic. The teacher must show many experiments as possible…Tinkerplots does it for us. How many dice? Computer does and we realize that it is rolling the dice…When we increase the number of rolls, the result gets closer to theoretical probability' (Zeynep, Interview 3)

Emine did not make such connections in her interviews, so it is not easy to make a conclusion about her TCK development by analyzing her results under technology in teaching process subcategory. She mentioned that technology was not an essential element in mathematics. Therefore there was a difference among participants of Group A in terms of mathematics with technology. In interviews 1 and 2 she stated her idea about technology in mathematics.

'I do not think technology is a must for mathematics…' (Emine, Interview 1)

'I do not see technology as must thing for mathematics teacher…' (Emine, Interview 2)

There was a decrease in Emine's post-test TPACK score when it was compared with her pre-test score. Her sentences above showed that she did not give role to technology in mathematics teaching and she was not sure about herself for using

educational technologies in a real classroom setting. One of the reasons behind her decrease of TPACK score in the course can be her negative views about using technology in mathematics education.

Participants in Group A gave a role to technology in learning process. They thought that technology made a difference in students' learning. Namely there was a contribution of technology for students. These contributions were stated as construction, recall and active participation. Berk implied that there was a difference between hearing something and doing it. Doing means constructing something. "When students construct, they know properties of it. They can grasp many details because of being a part of it in construction process" (Berk, Interview 3). Programs helps student to remember things easily according to Zeynep. When teachers use programs to teach a topic to a student, "the topic is in his/her mind" (Zeynep, Interview 2). By using programs, students actively participate in the learning process as Berk implied: "When student has a computer and teacher delimitates the conditions (if s/he uses GeoGebra in the lesson, s/he can use only it in the lesson), student will participate in lesson. Teacher can take attention of student by including the student in learning process" (Berk, Interview 1).

Visualization was the most commonly commented issue in technology in learning process. Participants appreciated technology for providing visual material to students' learning. All participants in Group A underlined the importance of visualization in mathematics learning. "Technology must provide visual things" (Emine, Interview 2). "If a student rotates a triangle in programs, s/he sees the way how it moves. This makes rotation visual. Therefore the student can remember easily" (Zeynep, Interview 3). Berk saw technology as a supporter of students in imagining two or three dimensional objects.

In Group A, all participants were aware of benefits of using technology in students' learning process. They gave examples about making students' learning easier by using technology and this referred to their TPK development throughout the course.

Group A's results under Personal Factors Theme

Personal factors made difference among participants in terms of integrating technology into mathematics education according to results of this study. There were six categories of Personal Factors Theme. These personal factors that affected participants' TPACK development in the course were personal effort, curiosity, experience, using what is learned, personal characteristic, and view about the course. In Table 9, there is representation of Personal Factors Theme.

Table 9. Personal Factors Theme

PERSONAL FACTORS THEME
Personal Effort
Curiosity
Experience
Using What is Learned
Personal Characteristic
Views about the Course

In Group A, only one participant had personal effort to use technology that was learnt in the course. The participant was Berk. At the beginning of the course, he made personal effort to use technology. He stated that he was good at using computer and in the process of the course; he showed personal effort to learn educational

programs and used them for teaching mathematics. His learning was not limited with the course. As stated before, he was working in a private institution. When he saw something interesting in his geometry teaching in private institution, he studied on it with educational programs at home. Namely he had personal effort to practice with educational programs about the things that he faced in his classes of private institution. This showed that in his TPACK development his personal effort had a role.

> 'In GeoGebra I learned many things by trying it. At the beginning I could not use hide/show commands in the program. Then I learned it by trying at home…' (Berk, Interview 2)

When I analyzed Zeynep's interviews, I concluded that she did not have personal effort for using technology but she was aware of that she needed personal effort to use educational programs. Without personal effort in the process of the course, she tried to deal with educational programs. Her learning was limited with the course according to results coming from interviewing. She stated that "I am not talented in technology but I do not deal with technology. I do not insist on learning". (Zeynep, Interview 1) She did not have adequate personal effort because she had an idea of being untalented in technology. When I analyzed my observation notes, I concluded that Zeynep did not make much effort in the course, too. "While others are working on the presentation, Zeynep is reading newspaper on the internet" (Field Note). This field note was an example about her lack of effort in the course to learn educational programs. According to my observations in the course, Zeynep did not participate in activities. For example, while they were studying Tinkerplots within the group, Zeynep was not as active as her group members. The reason behind this could be her lack of personal effort. She explained the reason behind her lack of personal effort.

She shared that there were three members in the group, she was not alone, and somehow the works in the group were done and she was not alone.

> 'Berk is using program. Emine is watching the computer screen and she intervenes from time to time. Zeynep is just listening to them' (Field Note)
>
> 'If I have to do it alone, I do…' (Zeynep, Interview 1)

When I look at Emine's interviews I did not find a personal effort to improve her in using educational programs. As Berk, Emine was working in a private institution, too. However Emine thought differently from Berk about technology. Since she did not need technology in private institution, she did not have personal effort to use educational programs outside of the course. Her dealing with educational programs was limited with the course.

> 'I did not use educational programs in my computer. Therefore I do not believe in me for using them...' (Emine, Interview 3)

In Group A, I concluded that Berk's TPACK development was affected by his personal efforts to use given educational programs in the course for teaching specific topics in geometry in his workspace. However his group members did not have personal efforts to use given educational programs outside the course and their developments were not affected by their personal efforts.

Curiosity was another subcategory that came out in results of Group A's interviews. Only Berk stated that he had curiosity towards technology and educational programs. Being curious about technology was a personal factor for Berk's TPACK development. He stated that;

> 'When I need a program, I find it, and I learn it. For example, I was curious about file storage. I searched it. I found programs. I learned.' (Berk, Interview 1)

This meant he was curious about computer programs. In his TPACK development, his curiosity about computer programs had a role. In Group A, Zeynep implied that she did not have curiosity towards technology and she showed this in my observations. I observed that she was uninterested in applications and presentations in the course. Emine did not mention curiosity.

Experience was one of the personal factors that shape participants' learning process in the course. In group A, Emine and Berk often shared their experiences from their private institutions, and they related their experiences with new learning in the course. However there was a difference between Emine and Berk. According to Emine's experiences, there was no need for technology but Berk did not think like Emine. Therefore Emine's experiences affected her development in components of TPACK framework negatively. She thought that:

> 'At private institution I am trying to teach topics to be permanent for students. Do I need technology? No. I can do my work without technology' Emine (Interview 1).

In her working environment, her aim was presenting topics in a memorable way and she did not need technology for this aim. Berk thought differently. He thought that technology could make his work easier when he remembered his experiences.

> 'In GeoGebra presentation, we presented the topic of drawing triangles that I taught in private institution. While I was teaching drawing triangles, one of my students asked me about a triangle whose lengths of edges are 5 cm, 8 cm and 13 cm. He argued that he could draw a triangle whose lengths of edges are 5 cm, 8 cm and 13 cm. I explained why he could not draw such a triangle by using my arms. There technology would make my work easier' (Berk, Interview 1)

Using what is learned was another category of Personal Factors Theme. In Group A, Berk used what he learnt in the course according to results coming from interviews. For example, he used Cabri 3D applications. He used previously prepared Cabri 3D videos in private institution for teaching pyramids. He thought using videos of Cabri

3D that could be beneficial for students. He implied that video applications prepared with Cabri 3D supported students' learning. I shared below a part on how he used what was learned in the course.

> 'There is a problem in pyramids about pyramid's height and side face height because there are vertical line segments in pyramids. It is confusing for students to separate them…We watched Cabri 3D videos on this topic. Then we discussed on requirements to construct a pyramid's height…'(Berk, Interview 3)

Sentences from his last interview showed me that Berk used educational programs for a specific topic in geometry to resolve a problem in students' learning. This indicated his TPACK development throughout the course. In Group A, Emine also worked in a private institution but she did not use what she learnt in the course. In this group Zeynep did not work as a teacher. Therefore this particular category was irrelevant for making sense of development in components of TPACK framework.

In the learning process in the course, participants' personal characteristics affected their TPACK development. In particular; Berk's personal characteristics affected his role, his participation and his working in the course. Berk had self-confidence in using computer and in doing mathematics. He stated that:

> 'I helped people in the course if they had a problem with technology. My friends ask me if they have a problem in Excel and PowerPoint. I can say that I am competent about technology. I can say that I am inclined to learn technology. I think that I am good at mathematics and geometry. Therefore I internalize technology, mathematic and geometry' (Berk, Interview 1)

Moreover he underlined that he could learn quickly. He said that: "seeing some properties of GeoGebra was enough for me" (Berk, Interview 1). He implied that he had qualification of leadership by which he took roles in the group work and studied with his group. I concluded that Berk's personal characteristics such as learning quickly and leadership made him active in using educational programs in the course and this helped him to develop his TK throughout the course.

Zeynep talked about her personal characteristics. Opposite to Berk, Zeynep's personal characteristics affected her TK development negatively. She thought that she "would slow down work in the group" (Zeynep, Interview 1) because she was not "fast enough" (Zeynep, Interview 1). Moreover she shared that she was not qualified in technology. Because of these personal characteristics according to my observations she chose not to be active in the course and this influenced her TPACK development.

Views about the course was another category of Personal Factors Theme. All participants had ideas related to the course. Their views about the course were different. Berk and Emine had a positive look about the course. Especially Berk thought that the course supported their learning about educational programs. According to Berk, course was effective in terms of supporting them to participate in all process in the course, improving ideas, watching others' studies. He added that "the instructor was not in an active position in the course. This was really important. For example, he did not show us every specific example. It was our imagination that could produce something with Cabri 3D. This was important for the course." (Berk, Interview 3). Emine was also pleased with the course. She thought that studying with different educational programs was good for her because there were not many courses for learning technology. In this course, she had a chance to meet different educational programs and she added that she did not learn programs in a detailed way. For this, she had to study personally. Zeynep had different views from her group members about the course. She thought that seeing three programs in a term was too much for her. She was complaining about short time to learn programs in a detailed way. She implied that in presentations everyone in the group knew about his/her part so she needed to make presentations personally.

> ‘We should do more than one presentation. Or we could do presentations personally. We needed more time to learn each program because I study with them first time…’ (Zeynep, Interview 3)

Group A’s results under Group Work Theme

Group A was selected according to maximum diversity in members’ TPACK scores. Participants with different TPACK scores at the beginning of the course worked in the same group throughout the course. I think this can make result under group work category coming from Group A remarkable. I will present two categories under results of Group Work Theme. These two categories are group-individual interaction and intra-group dynamics. There are two subcategories under group-individual interaction category: Studying with the group and Contribution of group to the individual. There are two subcategories under intra-group dynamics category: Views about group members, Rapport in the group, Role of a particular member. In Table 10, there is representation of Group Work Theme.

In the course, pre-service mathematics teachers studied in groups. They prepared presentations for using educational programs within the group. In this process, each participant interacted with the group. These interactions helped them to learn the programs, use them for teaching, and develop their TPACK. In the Group A, it was concluded that group-individual interaction did not occur well. I will present Group-Individual Interaction in two subcategories; Studying with the Group and Contribution of Group to the Individual.

Table 10. Group Work Theme

GROUP WORK THEME
Group-Individual Interaction
Studying with the Group
Contribution of Group to the Individual
Intra-Group Dynamics
Views about Group Members
Rapport in the Group
Role of a Particular Member

Studying with the group was a subcategory of group-individual interaction category. In the Group A, participants did not appreciate studying with the group. For example Berk underlined that he learns better alone. However Berk benefitted from one of the group members to learn basic tools in programs because he sometimes did not participate in the course. His knowledge about basic options of programs was supported by Emine. Emine taught him basic tools in the programs. This meant that Berk's TK development was supported by Emine when he did not attend the course. Then Berk improved himself by studying personally.

'I wanted Emine to teach me the programs, I can learn from her…' (Berk, Interview 2)

Berk liked shaping group's decisions. This was his view about group work as he stated below. In this group, last decisions were taken by advices of Berk. "When we met, I would give choices. Generally we decided what I said…" (Berk, Interview 3)

> ‘Today I showed something that I prepared to my group members…Normally other people discuss in the group. Some ideas emerge. At the end, I shape those ideas. That is my view about group work…’ (Berk, Interview 1)

Zeynep implied that group work was informative for her. Although she could learn better in a group, for her, interaction of individual and the group did not occur much. As it was stated above, Berk and Emine generally studied together. Zeynep sometimes worked with Emine but they could not solve some technical problems in the absence of Berk.

‘We could not construct Turkish Flag in GeoGebra with Emine. We got confused…’ (Zeynep, Interview 1)

According to my observations this group did not benefit from studying together. First of all they did not participate in many classes together. Emine was the one who generally came to the course. Interestingly, in the last course before Tinkerplots presentation, Emine was the only one who attended the course from Group A. In that course “since she was alone, she lost her motivation. She used her mobile phone to send sms” (Field Note). Secondly, when they were together, they did not study in a harmony. For example in a Tinkerplots study Zeynep and Emine were in the course. However they did not study together. They studied personally. Or they chose not to study.

> ‘Emine and Zeynep are not studying. Emine is using her mobile phone since beginning of the class’ (Field Note)

When all of them were in the course, they still did not study in a harmony. Berk was the one who used computer and directed the group. Emine and Zeynep were listeners and observers of Berk’s studies in the course according to my observations.

According to my conclusions in studying with the group subcategory as a result of my fieldwork, participants did not benefit from advantages of studying

collaboratively within a group. I think that studying with the group had a potential to support their development of TK, TCK, TPK and TPACK. Only one member Berk used this chance but he developed only his TK by studying with Emine when he did not attend the course. There is no doubt about importance of developing TK because it is a prerequisite knowledge component for development in TPACK. However studying with the group could affect development in other components of TPACK for not only Berk but also for Emine and Zeynep. I concluded that studying with the group affected only Berk's TK development in Group A.

Contribution of group to the individual was a subcategory of group-individual interaction category. In Group A, participants did not mention to a large extent about Contribution of Group in their learning. Only Zeynep indicated group's contribution to learn functions of programs.

'My friends helped me to learn functions of GeoGebra…' (Zeynep, Interview 1)

This specific case was only example of contribution of the group to an individual's learning for Group A. It was interesting because in the structure of the course, there was preparing and presenting their studies for each programs. In such an environment it was expected that group had a contribution in members' development of components of TPACK framework. However in Group A, I could not conclude about this. Therefore in Group A, I asserted that, there was not enough interaction of the individual and the group to support their development of components of TPACK framework.

TPACK development in Group A was affected from intra-group dynamics according the results of this study. I will present results in three subcategories of

intra-group dynamics of Group A. They are Views about Group Members, Rapport in the Group, and Role of a Particular Member.

Views about group members was a subcategory of intra-group dynamics category. In group A, Berk and Emine stated negative comments about their group member Zeynep. According to results they were not satisfied with Zeynep's role in the group. Emine's implications about Zeynep were worthy of consideration. She stated that:

> 'Indeed Zeynep was not in the group. If we were alone with Berk, we would have less stress. I understand Berk. He sometimes did not attend some of the lessons because he had to work. Zeynep was physically there but her soul was not in the class. She was just near me. I sometimes saw red because of Zeynep. I am a teacher. I must have tolerance. She is younger than me. I do not understand how her mind is closed…' (Emine, Interview 3)

These views showed me that, Emine had no confidence in Zeynep's presence in the group. Especially the sentence of "her mind is closed…" was a sign of Emine's negative views about Zeynep. Moreover Berk stated similar views about Zeynep. According to Berk, "Zeynep did not have any influence on idea development phase, application phase, and presentation phase" (Berk, Interview 3). Namely, Zeynep gave no support to them in the group as Berk stated. This was important. Two of group members had negative views about one group member's role in the group. They talked about why Zeynep was too passive in the group. Interestingly, the reason was related to Berk and Emine. The reason behind Zeynep's passive role would be Emine's and Berk's active characteristics in the course according to Berk and Emine as stated below.

> 'Zeynep was in very passive role. This could be a result of us. I and Emine were very active…' (Berk, Interview 3)

'Why was she passive? I think she had confidence in Berk and me…' (Emine, Interview 3)

In Group A, Zeynep and Emine had confidence in Berk's abilities in using technology. Emine believed in that males had abilities to use technology and she said that Berk supported the group at times of technical problems. She stated that:

> 'As I said males have different ability in technology. There is something in their nature for technical issues. I entered many classes but Berk understands with two sentences…' (Emine, Interview 3)

Emine's positive views about capabilities of Berk in using technology made her confident with Berk in the course. She said that she could give control of the mouse to Berk because she believed in his knowledge. My observations supported Emine's words. According to my observations Berk was the one who uses computer in their group works in the course. Emine added that she could not do same thing for Zeynep because she could do better than Zeynep. Zeynep also stated that Berk had "a special ability in these issues" (Zeynep, Interview 2) and by studying personally the programs he could use it. She added that:

> 'I think that Berk knows programs before. He knows very well. He makes works easier. When we want to do something, he knows well how to do it. He does directly.' (Zeynep, Interview 2)

However things were not the same for Berk. He did not have confidence in Emine's and Zeynep's abilities. Although he learnt some functions of programs in learning process in the course, he did all presentations and one of his group members used the programs. But this was not enough for him. He stated his desire to make presentation and using programs simultaneously as stated below.

'I wish to have chance to use computer while doing presentation…' (Berk, Interview 2)

The reason behind his wish was experiences during Group A's presentations as I noted in my observations. For example in their GeoGebra presentation, while Berk

was doing presentation, Zeynep could not construct a circle. Then Berk came to the computer and he constructed a circle and he kept up making presentation.

These results of views about group members showed me that in Group A, good intra-group dynamics did not develop in the process of the course. My first conclusion from "views about group members" subcategory was that Berk's and Emine's negative views affected Zeynep development in components of TPACK framework negatively. Zeynep was alone in the group. Her group members did not support her because of negative views about her. Therefore in her development in components of TPACK framework process she was generally alone. My second conclusion from "views about group members" subcategory was about Berk. Berk was also alone as Zeynep. However his loneliness affected his development in components of TPACK framework positively. He did not have confidence in his group members' abilities and his group members had a great confidence in his abilities. This made Berk the only one who could do works in the group. He was aware of being alone for many works in the group such as solving technical problems, using educational programs, and preparing presentations. Therefore in this process he learnt how to use educational programs and developed his TK. In preparing presentations, he used programs for specific mathematical topics and he developed his TCK. In this process he made presentations and he experienced using educational programs to teach mathematical topics in a micro-teaching environment and he developed his TPACK.

One of prominent intra-group dynamics was rapport in the group. In group A, there was not enough rapport. They were not comfortable with each other. Berk and Emine had problems with Zeynep in the group. They clearly stated these problems in interviews. One of the problems was coming late to group meetings. Emine and Berk complained about this event as Emine stated:

> ‘We had problems with Zeynep. She was coming group meetings very late. Berk was very angry about this problem. He said that he was regretful about Zeynep. He thought Zeynep grade form the course was not fair’ (Emine, Interview 3).

Zeynep was aware of her position in the group. She was not also satisfied with her group members. She clearly stated this in one of our interviews:

> ‘I: what are the difficulties that you face with the group?
>
> Zeynep: not difficulties. But my friends are working as teachers now.
>
> I: yes.
>
> Zeynep: they are good at teaching. If I was with friends who were in my knowledge level, it would be better because I would do something with them. Berk and Emine are more proficient than me.
>
> I: about what they are more proficient?
>
> Zeynep: I do not know. We are studying on a topic. We are making a lesson plan. I do not know how to practice that lesson plan. Can I really apply that lesson plan? They are better than me about this issue. They can talk about practice.
>
> I: they are working and this is the reason?
>
> Zeynep: I think so. Emine and Berk are working.’ (Zeynep, Interview 2)

In my observations, I noticed that Zeynep preferred to ask questions others instead of asking her group members. For example, “Meryem and Ece helped her to construct polyhedral by using Cabri 3D”. (Field Note)

In Group A, making group meetings were difficult and they did not have a plan to study. Emine and Berk stated about this mismatch in the group. Berk indicated that:

> ‘I and Emine are working. Therefore we cannot meet after class. We talked with Emine on internet… I barely showed my studies today because they did not come to the last class. We frankly do not have a plan…’ (Berk, Interview 1)

In Group A, Emine was active in the course. She tried to learn the tools in the programs and taught them to her friends and Berk prepared presentations. This showed that in Group A individuals were in the foreground. Emine learned, she

taught Berk and Zeynep, (especially Berk) Berk studied and prepared presentation. Therefore Emine's role in Group A was like being a bridge between the course and her group members and she was not satisfied with her position in the group. One of the courses she complained about her friends. She says that "you made me so tired…" (Field Note) while she was teaching using Tinkerplots. I concluded that there was no rapport among group members in Group A. Lack of rapport among group members prevented them from having suitable studying environment outside the classroom. Moreover especially Zeynep was affected negatively from lack of rapport with her group members. Berk and Emine formed a discussion environment via internet but Zeynep was out of this environment. In Group A, because of lack of rapport in the group, participants did not have a suitable studying environment in which they could discuss and study about educational programs, mathematical content area, and prepare presentation with educational programs. Therefore they lost a chance of development in components of TPACK framework because of lack of rapport in the group.

Role of a particular member was a subcategory of intra-group dynamics category. In Group A, Berk had influence on group members. He helped his friends for technical problems. When they could not do something in programs, they asked Berk. Emine stated that:

> 'Sitting with Berk is very useful to me. I study with him. When I cannot do, the instructor becomes busy. I can ask Berk. He supports me. This is too beneficial for me. When Berk does not come to the class, I say sadly Berk should be here…' (Emine, Interview 1)

Zeynep added that:

> 'While Berk is using programs, I can resolve my problems with the programs whereby I can use it when I need…' (Zeynep, Interview1)

Therefore according to group members of Berk, Berk's existence was good for them. Berk supported them in the course in technological issues. Moreover, Berk affected groups' decisions. For example, while selecting the topic for group presentation, Berk's ideas were crucial. His role was implemented by Emine and Zeynep in interviews.

> 'I: why did you change your topic?
>
> Emine: Berk came. He changed everything. He said that he did something. He prepared something at home. We talked on it. We tried to prepare a lesson plan.' (Emine, Interview 1)

'Emine and I had some ideas but at the end we did what Berk said…' (Zeynep, Intervew 2)

In the field notes, Berk's role was seen clearly. The following part was an example of his active role in the group.

> 'Berk is explaining thread of their presentation. He implied that asking questions to students help students to think on the topic. He is talking about their aims in this presentation…' (Field Note)

This was one of my comments from my field notes:

> 'Berk always use computer in this group. When he is in the group, group discussion shapes around his ideas.' (Field Note)

As it was seen in this quotation that in Group A, there was one particular member who came forward: Berk. He had an important position in terms of his support about technological issues and decision making process of the group. In Group A, I concluded that Berk had an effect on his group members' TK development because he was the one who solved problems in educational programs. When Zeynep and Emine could not do something, they had chance to ask Berk and learn from him. Therefore Berk had a considerable role in their development of TK. Moreover Berk's role in the Group A, affected his development of TK, TCK, TPK, and TPACK. In the

process of the course, he had many responsibilities in the group such as using educational programs in the course, giving decisions about presentations' topics, preparing presentations, and making presentations. All these responsibilities made him mentally active throughout the course which supported his development of TK, TCK, TPK, and TPACK according to my conclusions.

In Group A, Emine was the only one who started with the highest TPACK score in pre-test and decreased her score in post-test. Results under Group Work Theme can explain her decrement from pre-test to post-test. As I concluded that dynamics of group work did not work well in Group A. They did not study collaboratively in the course. They generally showed a disorganized study style in the group. Namely there was disharmony among group members. In this process, Emine was uneasy about this situation. She was not happy about her position in the group. She defined herself as a bridge between Zeynep and Berk. Emine tried to attend almost all classes of the course. However her friends were not with her. In other words in some courses she was alone and she was complaining about this situation in her interviews. According to my conclusions decrease in Emine's overall TPACK score from pre-test to post-test can be explained by lack of harmony in Group A. Dynamics of group work did not work for Group A. They did not benefit from possible advantages of group work. Emine was mostly affected from this situation because she was the one who try to attend all classes and organize her friends. However she did not succeed in this and disharmony among group members caused her TPACK decrease throughout the course.

Group A's results under Structure of the Course Theme

Structure of the course was concluded as a factor about explaining how components of TPACK framework develop. In two categories I will present results under Structure of the Course Theme. They are content of the course and the instructor. In Table 11, there is representation of Structure of the Course Theme.

Table 11.Structure of the Course Theme

STRUCTURE OF THE COURSE THEME
Content of the Course
Learning about Educational Programs
Views on educational programs
Experiences with educational programs
Applications in the course
The Presentations
Preparing presentations
Making presentations
Watching other groups' presentations
The Instructor

Content of the Course will be presented in two subcategories. First one is learning about educational programs. The second one is presentations.

In the course, participants' views on educational programs, experiences with educational programs, and applications in the course affected their learning of educational programs according the results of Group A.

Participants in Group A stated their views about educational programs. They did not have same views for all programs. Therefore I will present their views one by one. Firstly for GeoGebra, participants stated different views. Emine implied that she

did not think using GeoGebra in her teaching in the future. GeoGebra was not among her potential teaching materials in the future. Berk did not state parallel ideas with Emine. He mentioned that he had a plan to benefit from GeoGebra and he shared his plan. Berk implied that his aim was not to teach functions of GeoGebra in a classroom. His focus was on mathematical topics that could be taught with GeoGebra as he implied:

> 'We do not use GeoGebra to teach program. We use it to explore, comprehend and identify a concept...My aim is bringing my students mathematical concepts with GeoGebra...' (Berk, Interview 1)

For Zeynep, teaching functions of GeoGebra in the classroom came first. At this point her ideas were different from Berk's. Berk's focus was teaching mathematical concepts by using GeoGebra whereas Zeynep's primary focus was properties of program. She said that firstly she would teach functions of program.

Participants in Group A had similar ideas about Tinkerplots. They thought that Tinkerplots was an incomplete program. They were not sure to use it in the future for teaching. Here I will refer to Emine's views about Tinkerplots as representative of the group's:

> 'I think Tinkerplots is a difficult and limited program. There is histogram and probability. I have to study just for them. I felt restricted…' (Emine, Interview 2)

This statement was representative of group's general point of view. Moreover Emine was not satisfied with many movements in Tinkerplots. She underlined that many movements could affect students' attention negatively.

Cabri 3D was seen as a beneficial program for teaching three dimensional objects. Participants thought that teaching and learning three dimensional objects were difficult. They stated that Cabri 3D had potential to pass difficulties in three

dimensional objects. Zeynep implied that students had difficulties about abstract thinking in three dimensional objects. According to Zeynep, students' difficulties in abstract thinking could be resolved by Cabri 3D. This showed me that Zeynep was aware of students' potential difficulties in a specific topic in mathematics and she underlines potential benefits of using Cabri 3D for resolving them. This indicated Zeynep's TPACK. Berk also viewed Cabri 3D as a very good program. He made a comparison of teaching three dimensional objects by using the board and with Cabri 3D. In this comparison, I concluded that Berk developed his TPACK because he identified a specific topic in mathematics, he stated about students' potential difficulties, and he found a solution by using Cabri 3D for students' potential difficulties in that topic.

> 'We are drawing three dimensional objects on the board. Then we call it three dimensional but students are not satisfied. For example, you are constructing a cube and teaching vectors. Students cannot comprehend movements' of vectors. Or they cannot find measurement of the angle between object diagonal and face diagonal. Cabri 3D is a very good programs to realize them.' (Berk, Interview 3)

In Group A, participants have some difficulties with educational programs. These natural difficulties enable them to be aware of their inadequacies. Problems that they face, show them what they cannot do and what they can improve with programs. For example in GeoGebra, Zeynep and Emine have difficulties to construct Turkish Flag. They cannot fix the Flag. When they move something on the flag, crescent and star turn irregularly. They know that they have to use a slider but they cannot succeed. Both of them state that this is a result of their inadequacy in using GeoGebra.

Participants also face with problems in Tinkerplots. Their experience is formed around those problems and solving them. Berk state that computer stops

when they study with the numbers of six digits. Then they use smaller digits to solve this problem. Emine complains about crash problems (a problem that cause of Tinkerplots in one of our interviews:

> 'In my computer Tinkerplots generally showed crash problem then it closed. Then I used the instructor's computer. The program has this kind of hitches…' (Emine, Interview 2)

Difficulties that they faced in using educational problems lead them to find new solutions. They saw their inadequacy in using educational programs and developed themselves. I concluded that dealing with difficulties enabled participants to develop their TK.

In the applications of the course, participants became aware of using given programs for specific mathematical topics. Emine stated her idea of increasing number of applications in the course. Her learning was dependent to applications in the course. She indicated that:

> 'When I teach something, I do not think about integrating technology. Therefore we need to see more examples in the program related to different mathematical topics in the course. We do such examples in the course but we need more…' (Emine, Interview 2)

Since she did not think about how to benefit from educational program for a given mathematical topic, applications in the course were important for her. In Group A, Zeynep said that she could not follow applications in the course.

> 'In the course, when the instructor shows steps of using the programs, I cannot understand those steps. These steps must be told clearly…' (Zeynep, Interview 2)

Zeynep's and Emine's sentences showed me that participants TK development was dependent to applications in the course because they saw how to use given program step by step. For Zeynep and Emine, it was important to see firstly form the instructor then making that application individually.

In the course preparing presentations, making presentations and watching other groups' presentations supported participants of Group A to improve themselves in using the programs for educational purposes.

In Group A, Berk was the member who prepared and presented all presentations. His group members wanted him to make presentations and he accepted. Emine saw making presentation as a risk for her:

> 'I do not remember when I last made a presentation. I did not risk the presentations. Therefore Berk made all of them. If he did not accept I would make…' (Emine, Interview 3)

Berk mentioned that he made all presentations because of his English:

> 'They had confidence in my English…Emine insisted much. Therefore I made first presentation…I made all presentations…' (Berk, Interview 3)

In this process of making presentation I concluded that he was mentally active. This meant that he thought using programs, using programs to teach which topic, and aim of the presentation. I will share Berk's view on his Tinkerplots presentation to show how he was active because of doing presentations:

> 'Our aim was to teach the difference between dependent and independent events. What does change? Why is an event dependent or independent? Students may have problems with changing sample space in probability. In the dependent event sample space changes, so in each step sample space must be calculated again. Our aim was to teach this in Tinkerplots' (Berk, Interview 2)

In the sentences above he explained how to find a solution to students' difficulties on a specific topic by using Tinkerplots. This indicated his TPACK. Although Tinkerplots was not appreciated by all participants in Group A, Berk's TPACK showed itself in the interview on Tinkerplots. This showed me that making a presentation had a crucial role in TPACK development throughout the course.

While Group A was preparing the presentation, members of the group improved themselves how to use available technology for educational purposes. I will share Zeynep's words. Zeynep shared GeoGebra presentation process and their aim in presentation clearly. Preparing Presentation helped her to integrate educational technology with mathematical content.

> 'In GeoGebra we want to prepare a presentation with a constructivist view. We put sliders. While moving sliders, triangle is constructed or not. What are the lengths of sides when triangle is constructed? We want them to make meaning of $|a-b| < c < a+b$. To realize this, students must see many examples in GeoGebra.' (Zeynep, Interview 1)

I concluded that preparing presentations contributed to participants' TCK development. Although Zeynep was not an active member of Group A, she could relate a mathematical topic with GeoGebra and she explained how to use GeoGebra to present the topic.

In group A, Berk learned from watching other groups' presentations. He learned what he could not individually. He stated the importance of watching other groups' presentations in the course clearly during his interviews:

> 'One group presented mode median and standard deviation. They showed with a good schema. Another group presented polygon's external angle. It is an important topic. It is 7^{th} grade's topic. I sometimes faced in my private lessons. Students can take all part as external angle except internal angle. One group implied this. In this process we shared others' experiences. We see what can be done with the programs. We can improve ourselves. We can realize our inadequacies. We force ourselves to be better. These are very important.' (Berk, Interview 3)

> 'I could construct a slider at home. But I could not construct a cylinder on a plane. I could not do it with a height that I want. Today, in presentations I learned it. Firstly, he is constructing a vector, and then he is constructing a vertical line. He is selecting a point on it and constructing a cylinder according to the vector. I learned this in the course while watching presentations…' (Berk, Interview 2)

This showed me that Berk was an active listener in other groups' presentations. My observations were consistent with Berk's words in his interviews. In my field notes I

concluded that Berk participated in other groups' presentation by asking questions and sharing his ideas.

> 'Berk is listening well. He is different from others. For example Zeynep, Ece and Aslı are looking at their computers and searched in the internet. Berk is just looking at the presentation' (Field Note)
>
> 'Berk said that Tinkerplots is a beneficial program to teach dependent events after second groups' presentation' (Field Note)

These results showed me that Berk's TK development was affected by watching other groups' presentations.

The instructor was a category under Structure of the course theme. The instructor of the course had contribution in participants' learning. In group A, participants needed the instructor. They needed the instructor to ask about using the programs. In the course, according to results of Group A, the instructor supported all pre-service mathematics teachers in the class. In the class participants ask him about what they cannot do with the programs.

'Today, we could not do and we asked instructor…' (Zeynep, Interview 1)

The instructor tried to answer questions of pre-service teachers during the course according to my observations. "While pre-service teachers are studying about the given task, the instructor is going to their desks. He is answering their questions. Moreover he is asking questions to pre-service teachers about their studies" (Field Note). However I also had field notes about the instructor was busy during the class. Sometimes he did not answer all questions. Emine complained about this situation, as seen in the extracts below. She was advising an assistant for the course. The results showed me that the instructor had a role in pre-service mathematics teachers' learning about how to use the educational programs.

> ‘We could not do. We told the instructor. The instructor was busy. Our turn did not come. The instructor said that he would answer after class but I had to go after class…’ (Emine, Interview 1)
>
> ‘The instructor was too busy. He was trying to answer everyone. He was helping everyone. He tried to do his best…’ (Emine, Interview 3)
>
> ‘In the course, there is a need for an assistant. The instructor was busy. An assistant is needed in the course to answer our questions…’ (Emine, Interview 3)

In this course, although the instructor was too busy in the class, he was available after the course.

> ‘After the class, we could get the instructor’s support. If there was something inadequate in the class and the instructor was available, we could ask to the instructor after the class…’ (Emine, Interview 3)

These results showed me that the instructor had a crucial effect on Zeynep’s and Emine’s TK development. Whenever they could not use the program they requested his support. At this point, I distinguished Berk’s TK development from his group members. Since he did not attend some of the courses because of his work, he did not share anything about his instructor’s affect in his learning throughout the course.

In this section firstly I will introduce the members of Group B, and then I will present results from Group B’s interviews and observation with respect to themes, categories and subcategories.

Information about participants of Group B

In this section firstly I will introduce the members of Group B, and then I will present results from Group B’s interviews and observation with respect to themes, categories and subcategories.

In Group B, there are three participants. Their TPACK scores in the pre-test are similar to each other. Namely Group B is a homogenous case in terms of participants’ TPACK scores.

Meryem is a senior pre-service mathematics teacher. She is in her seventh term in university. She is 22 years old. She has personal interest in using technology. She likes studying with technology. For example, she mentions about a website. She develops a website in a summer holiday. Although she does not know how to develop it, she learns it in the holiday by herself. Meryem is curious about using technology. She uses her personal computer for social networks, e-book, games, and resources for education. Especially she is an active user of facebook and twitter and she uses her smart phone to be online. She appreciates using technology for teaching. She gives private lessons and she says that she uses computer to teach. She generally uses educational games to teach as she stated in her first interview.

> 'I and my student played a game in computer about multiplication table. It was beneficial for my student.' (Meryem, Interview 1)

Aslı is a university student who has three terms to finish her school. She is 23 years old. She does not have personal interest in technology. Although Aslı does not like to learn properties of technological tools in a detailed way, she enjoys searching and learning new technological inventions. She uses her personal computer for social networks, watching TV series, and doing homework. She can use Microsoft Office programs such as Word, PowerPoint, and Excel to prepare her homework and presentations.

'I generally need Excel, Word, and PowerPoint. I know how to use them.' (Aslı, Interview 1)

Ece is a senior pre-service mathematics teacher. She is in her seventh term in university. She is 22 years old. She does not have personal interest in technology. In her interviews it is seen that she is not good enough in technical issues in technology. She adds that she is an active user of social networks such as twitter and facebook.

She generally uses internet for reading newspaper and watching movies. She uses video downloading programs. She can use Microsoft Word and PowerPoint. She implies that she forget using Microsoft Excel.

'I can use Word and PowerPoint. I did not remember how to use Excel…' (Ece, Interview 1)

In the following sections, I will present results of Group B under four themes. These themes are technology theme, personal factors theme, group work theme, and structure of the course theme.

Group B's results under Technology Theme

Technology Overview is a category under Technology Theme for Group B's results. Meryem, Aslı, and Ece had parallel technology overviews about position of the technology nowadays. They were aware of their environment. They stated that many students in primary schools had laptops and tablet computers. Technology was an ordinary thing in new generation's lives. Therefore as pre-service teachers they implied that technology was an urgent thing for them. Meryem stated that:

> 'We are in the age of technology and it will have reflections on education…Tablet computers are growing up and teachers must follow technological improvements…' (Meryem, Interview 2)

Aslı mentioned that she viewed knowing technology as a benefit in her job. She stated that a teacher who could use technology had chance to find job when compared with others who could not users of technology. Aslı also thought that people had different and better views about a teacher who was an active user of technology. Aslı's technology overview was formed around these ideas. When I looked at Ece's technology overview, I saw similar motives behind her technology overview. She also viewed technology as indispensible because of the requirements

of our age. These results showed me that participants in Group B had positive views on technology because of its necessity for today's generation. They were aware of being capable of using technology in today's life. As teacher candidates, it was crucial for them to have adequate TK in today's classrooms. I concluded that participants' technology overview had a role in their TK development throughout the course.

Technology in Education was another category of Technology Theme. For the participants in Group B, TPACK development was affected by their views on Technology in Education. Participants' views on Technology in Education were formed under two subcategories; Technology in Teaching Process and Technology in Learning Process.

In Group B, participants' adding technology into their PCK was actualized by viewing technology as a part of teaching process. Technology had some roles in teaching process according to the results of Group B. Meryem and Ece implied that technology saved time in teaching mathematics. Meryem said that on a blackboard, teachers used much time to make smooth drawings but technology quickens things. Ece shared similar ideas with Meryem and Ece added that:

> 'I think that using technology is more useful for saving time. It is more efficient. You can do better studies in a shorter time. I think that by using technology, you do not need to distribute many materials to all students. You can easily show your material when you benefit from technology.' (Ece, Interview 3)

Their GeoGebra presentation was an example of using time effectively in teaching mathematics. In their presentation, they studied rotating polygons around the origin. At the beginning they constructed a triangle and rotated it clockwise and counterclockwise. Then they implemented same process for a square. At the end, Ece

(acted as a student during the presentation) constructed a square with the guidance of the teacher (Meryem acted as a teacher during the presentation). At the end, they made a discussion about what they did. Therefore in a short time they could use their time effectively by using properties of GeoGebra. They were aware of a potential benefit of using technology in education. They explained how to use given educational programs to save time and this was evidence of their TPK development throughout the course. Moreover in their presentations they showed an example of saving time by using GeoGebra in a specific mathematical content. This was evidence of their TPACK development throughout the course.

In Group B, participants stated that technology had a role of manipulation in teaching process. According to the field notes manipulation was emphasized by the instructor as a benefit of using technology in classroom. He stated that "GeoGebra may be manipulated by the teacher. The teacher can limit some tools for students in GeoGebra" (Field Note). In other words, the instructor emphasized a pedagogic benefit of using technology in classroom and participants were aware of it as they stated in their interviews. This showed me signs of participants' TPK. According to participants, by using technology teachers had chance to change things in their drawings. For example as Ece stated, a teacher could change lengths of sides in constructing a triangle and the teacher could change height and width of a geometrical object. Similarly Meryem mentioned that teacher could move objects by using technology. Therefore a teacher had a chance to change something on the objects. Normally on a blackboard a teacher could not manipulate things without cleaning it but technology gave this chance of manipulation to the teacher in teaching process.

In a technology integrated classroom, "it is very crucial for a teacher to integrate his/her content area and technology, s/he must have technological knowledge in his/her content area" (Meryem, Interview 3). This was an important idea because it was definition of TCK, and Meryem gave this definition in her last interview. This showed me that she developed an idea about importance of having appropriate TCK for a teacher. According to results of Group B, in teaching by using technology, teacher's role changed compared to a classic classroom environment. All participants were aware of this change. Meryem stated that not only in the classroom but also outside the classroom teacher's role changed. She mentioned that:

> 'Does a material have a value for education? When I use it in the classroom, is it suitable for the topic? It is very important. There are many websites. There are many lessons via video. However are they suitable for using in the classroom? A teacher has responsibility to have knowledge about technology to make right choice…' (Meryem, Interview 2)

In technology integrated classrooms teachers had some responsibilities. Ece thought that a teacher must know well using technology. Namely she underlined the importance of having proper TK for a teacher. If the teacher could not perfectly use technology, a chaotic atmosphere was inevitable in the classroom. According to Ece, "there is no meaning of using technology in the classroom unless the teacher has sufficient technological knowledge. If the teacher cannot answer students' questions, s/he cannot reach the actual objectives. It becomes an aimless activity. Therefore it is good to use technology but it depends on your knowledge" (Ece, Interview 2). According to my observation in the course, participants' main aim was learning tools of given educational program. They tried to develop their TK throughout the course because as stated above they were aware of importance of knowing well to use educational programs. For example in the last class before Tinkerplots presentation,

members of Group B study basic properties such as constructing bar graphs. According to the interviews they did not feel comfortable with using Tinkerplots and in the last class of Tinkerplots they still studied basic properties of the programs. According to them the teacher's knowledge was a prerequisite for integrating technology into classroom. If the teacher integrated technology into classroom, his/her role changed in classroom activities. According to participants, teacher must be active in a technology integrated classroom. For example Aslı indicated that:

> 'Teacher must move around the students to check their studies. The teacher must control all students one by one.' (Aslı, Interview 1)

In this group all participants state that teachers must control all students. If this can be accomplished, using technology makes teaching easier for teachers. Meryem implied that teacher's work was teaching and teaching with technology was easier than teaching without technology if s/he could control technological tools of students such as tablets.

Participants in Group B developed an idea for using technology in real classroom setting throughout the course. They developed pedagogical ideas when technology was integrated in a classroom. This gave me evidences of their TPK development. According to Meryem, there must be some rules about using computers in the classroom. These rules were decided at the beginning of the semester and they must be remembered to the students from time to time. In a real technology integrated classroom setting peer interaction was appreciated by members of Group B. Aslı states that:

> 'I regulate my class's sitting scheme in a way that students can help each other. In a computer based class, a higher achiever and a lower achiever can sit together. They study together. Then I separate them and I look their studies one by one' (Aslı, Interview 2)

In a real classroom setting, a useful way of using technology was making students active according to all participants in Group B. Ece denoted that "just showing on one screen is meaningless for teaching. Students need to work on the computers themselves. It is better. When students use technology individually, they can learn better. In computers educational programs will be loaded and teacher will use them with students" (Ece, Interview 2)

Ece and Aslı thought using technology with students is not easy in a real classroom setting. They had complaints about Turkey's educational system. Ece implied that in Turkey, mathematics curriculum is too intensive. Aslı stated that Turkish educational system was exam oriented. Therefore it was not easy to satisfy students' needs by using educational technology. These two participants were aware of potential problems of using technology in a real classroom setting. In Group B, Meryem stated classroom management as a potential problem in a technology integrated classroom. Meryem says that:

> 'I need to have a detailed plan. What are my objectives? What is my aim about using educational technology? I think that having a plan is very important.' (Meryem, Interview 1)

In a real classroom setting having a lesson plan makes teaching effective if teacher use technology according to Meryem. Making a lesson plan was the solution of Meryem for potential problems as classroom management.

In Group B, participants related mathematics with technology. Meryem implied that technology is used when it is required. Participants answered the question about when technology was required by stating that some mathematical topics were suitable for some educational programs. This showed me that,

participants could relate educational programs and mathematical contents. Ece stated that:

"Domains of two programs are different. Tinkerplots is statistics program. I cannot teach a topic related to statistics with GeoGebra. If I say that I will use technology, I must know using both of them effectively" (Ece, Interview 2) and she added that she could benefit from GeoGebra in mathematical contents of symmetry, slope, and proofs of geometrical objects such as triangle. Ece and her group members could distinguish proper contents for given educational programs in the course. Making this distinction was a property of a teacher who had appropriate TCK. Therefore I concluded that participants in Group B developed their TCK throughout the course.

Participants in Group B gave some roles to technology in learning process. In learning process technology had some contributions to students. These contributions were stated as construction, active participation, increasing self-confidence and visualization. Meryem implied that technology was a tool for constructing in learning process. She gave an example from Cabri 3D:

> 'I liked Cabri 3D a lot. This program does not support rote learning. I think it is suitable for constructivism because you must build things in stages. For example, you do not directly draw a prism. What do you need to construct a prism? You need a base. So you draw one lower base. You need a height. So you must construct objects on them' (Meryem, Interview 3)

In this construction process students had possibility of making mistakes. According to Ece these mistakes were part of their learning process. They could find the right way by doing mistakes and students' learning would be more permanent by using technology in education.

Active participation was another contribution of technology in learning process. All participants in Group B stated about this contribution. One participant,

Ece, stated about active participation by comparing a classic classroom environment with a technology integrated classroom environment:

> 'When we were students, we would sit and listen. We were like that. We would just sit and take notes and we would go to the board for solving questions. However students become more active in a technology integrated classroom. Students see more and are curious. They ask questions. They try by using educational programs. Students examine the reasons of activities in the program.' (Ece, Interview 1)

In Group B, technology had potential to increase students' self-confidence in learning process according to Aslı and Meryem. They thought that students become aware of their potential by studying in educational programs because they study alone. If their self-confidence increases, they can do mathematics better.

Visualization was commented by all participants in Group B for Technology in Learning Process. Technology provided visual materials for learning of students. Group B's presentation for Cabri 3D is a^3-b^3. The reason behind this choice was explained by Ece:

> 'I cannot know it. I did not memorize it. I do not know formula. We chose it to visualize the formula. No one wants to memorize the formula. If they visualize it, they can learn better.' (Ece, Interview 3)

Therefore their choice was visualization of a^3-b^3. Aslı stated that three dimensional objects were difficult for her in primary school. She thought that it was a difficult topic for students. The problems in three dimensional objects could be solved by using technology because technology increased visualization. Meryem added that the reason why she liked Tinkerplots was visualization. She stated that Tinkerplots' visualization was proper for students in primary education.

Results coming from "technology in learning process" subcategory showed me that participants were mentally active about potential benefits of using technology for students' learning. In other words they developed their knowledge in terms of

pedagogical aims of using technology in education. It can be claimed that all participants' in Group B developed their TPK throughout the course.

Group B's results under Personal Factors Theme

Participants' development in components of TPACK framework in the course was affected by some personal factors. There are six categories for personal factors theme. These are personal effort, curiosity, experience, using what is learned, personal qualifications, and views about the course.

In Group B, Meryem's development in components of TPACK framework in the course had a relation with her personal effort. She was aware of the structure of the course. She said that in the course the instructor introduced some educational program and he taught some basic properties of given program. Meryem stated that she needed to study personally to improve herself and use program in a detailed way. She knew that she needed personal effort to use technology in teaching process and she had personal effort. She mentioned her personal effort to use educational games in her private lessons:

> 'I look at things in terms of educational value. If we need, we can benefit from everything. Technology is important for this point of view. For example, yesterday I gave a private lesson. My student was a 4th grader. She did not completely know multiplication table. I searched for a computer game about multiplication table before the lesson. Yesterday we played that game in the lesson. It was beneficial for her learning.' (Meryem, Interview 1)

Meryem had personal effort to benefit from technology. Searching for educational games was one of the examples for her personal effort to use technology. She also had personal effort to use educational programs given in the course. I concluded that her personal efforts had a potential to affect her development in components of TPACK framework. To be specific her TK development was especially affected from her personal efforts because she was aware of need for study individually to

learn educational programs. Her primary focus was increasing her knowledge about using programs. This indicated an effort to develop TK which was a prerequisite knowledge component TPACK development.

In Group B, Meryem's curiosity came forward in her development in the course. Ece and Aslı did not seem as curious as Meryem about using educational programs personally. They accomplished their tasks in the course as I observed but they did not imply that they were curious about educational technology. Ece shared that she was not curious about technology. Aslı indicated that she knew about new technologies but she was not interested in details of them. However Meryem mentioned that she had personal interest for technology. Her personal interest was not only for educational technology given in the course but also for educational technology outside of the course's syllabus. This issue was apparent in the following quote:

> 'In the summer, I tried to learn some programs. I studied with adobe flash. I used it much. Then I did not take course of Instructional Technologies and Material Development. I was curious about Dreamweaver. I used it in the summer.' (Meryem, Interview 1)

Meryem's curiosity showed itself in the process of the course. For example she said that "send data set to me, I want to try it in my computer" (Field Note) while they were studying with Tinkerplots. For another example in the last presentation of the group, they chose a difficult topic for using Cabri 3D in comparison with other groups' presentations. Group B's presentation topic was visual representation of a^3-b^3 in Cabri 3D. Selection of a^3-b^3 was the idea of Meryem. When I asked her about reasons of this choice, I found out that Meryem's curiosity was the reason. She mentioned that:

> ‘It was an interesting topic. I think it was not a good choice for presentation. However I tried to see how our learning in the course avails. We tried to improve ourselves. The important thing is what I learnt in this process. Therefore I liked it.’ (Meryem, Interview 3)

I concluded that her implication above was important for her TCK development. She implied that she wanted to see whether her learning in Cabri 3D worked or not. She was curious about this. To test this, she made a difficult choice such as visual representation of a^3-b^3. This showed that she related a specific mathematical content with a specific program. Namely she tried to use her TCK in this process.

According to results of Group B, experience was a personal factor that had role on participants’ TPK development. How do they prepare physical environment of a technology integrated classroom? How do they plan a lesson with technology? How do they behave in a technology integrated classroom? Does using technology beneficial for students? Answers of these questions were given by Meryem and Aslı in Group B according to their personal experiences. Meryem stated that students could be seated around a circle in a technology integrated classroom. Her idea was formed because she taught a lesson in such an environment. Meryem also thought that a teacher must plan all parts of a lesson if s/he will use technology. Because she explained that once in a lesson she did not have a plan and that lesson is a very bad experience for her and she added that the teacher must attract the attention of the students before using computers. She experienced importance of attracting attention before starting in a lesson as she states in one of her interviews. In Group B, Aslı shared her experience about using technology. She used mathematical games in computer within a project and she developed the idea that using technology was beneficial and enjoyable for students. In Group B, Aslı and Meryem made use of their experiences coming from their private lessons. These experiences gave them chances to observe students’ learning and they associated their experiences with their

knowledge about educational programs. Therefore I concluded that their TPK development was related to their experiences.

In Group B, Meryem used what she learned in the course. Meryem used educational programs taught in the course in her private lessons. She gave examples about how she used Cabri 3D. Following was one example from Meryem's using of Cabri 3D in her private lessons:

> 'My student used Cabri 3D. I just guided her. I asked about what she needs to construct a prism. How do we term a prism? What do we need to construct it? How can we draw it? I directed her with my questions.' (Meryem, Interview 3)

Meryem was an active user of educational programs given in the course. The reason behind this was her private lessons. She had proper environments to use educational programs for teaching and she preferred to use. In Group B, in her final interview Ece stated that she will use Cabri 3D. She found a proper environment to teach with Cabri 3D. She stated:

> 'I started to work in an institution related to gifted students. I will use Cabri 3D. I will plan a two months program for them with Cabri 3D…' (Ece, Interview 3)

Ece's situation showed me that having proper environment was important while considering using what is learned. Meryem had such an environment and she used it to experience what she learned in the course. She found an environment to try using educational programs in teaching processes. In her interviews she explained the process of using educational programs to teach mathematics. I concluded that her TPACK development throughout the course was affected from her usage of what was learned.

According to results of Group B, participants' personal characteristics affected their development in the course. In this group, Meryem thought that she

improved herself in this course to accommodate technology with her content of mathematics. This indicated that she was concerned with TCK. She stated that she could use all educational program taught in the course. Her group members had similar ideas with Meryem but there was one exception. They thought that they were not ready to use Cabri 3D effectively. In Group B, all participants thought that it would be better to study more on educational programs taught in the course. With this study, they stated that they could improve themselves to use educational programs in teaching effectively. In other words they needed more experience with educational programs. I concluded from their words that they gave an important role to TK to use educational programs in teaching process. Since TK as a prerequisite knowledge component of TPACK framework, their idea was consistent with arguments of TPACK framework.

In Group B, all participants had positive views about the course. They appreciated to learning different educational programs in one course. They saw this as a chance for them for their future life in teaching. Aslı stated that:

> 'I say that fortunately we get this course. I like it. We learn many different things. I think many universities do not have qualified computer education. Learning many different things make us qualified teachers. It is very important' (Aslı, Interview 2)

Moreover Aslı implied that she refreshed her knowledge about geometry in the course. She indicated that she forgot many things about geometry and in the course she remembered them. This meant that she increased her CK throughout the course. She increased her CK by using educational programs in the course. Namely she had to relate her developing CK with her TK. Therefore I concluded that she developed her TCK throughout the course.

Group B's results under Group Work Theme

Studying with a group was a part of the course. According to my observations in the course participants' main focus was learning options of given program. They tried to recognize basic tools of educational program in the course. Participants are needed to study within the group to increase their knowledge about using educational program. At the beginning of the course, pre-service mathematics teachers decided their group members. In Group B, Meryem, Aslı, and Ece studied together throughout the course. They supported each other in the course and outside of the course. According the results of the study, their development in components of TPACK framework was positively affected by Group Work. Under Group Work Theme there are two categories: group-individual interaction and intra-group dynamics.

Participants in Group B worked in a harmony along the course. In the group, they learned together. In the course, they supported each other to learn educational programs. Outside of the course, they prepared presentations with educational programs. In this process it was inevitable for them to interact with the group. According to results of Group B, group-individual interaction occurred well and it supported participants' development in components of TPACK framework. There are two subcategories for Group-Individual Interaction category: Studying with the Group and Contribution of Group to the Individual.

All participants in Group B appreciated studying with the group. They stated that studying with the group was very beneficial for them. Aslı mentioned that:

"I think studying with the group is better for us. We can ask each other about functions of program. One of our friends explains it. If three of us do not know a

thing, then we ask the instructor. I like my group because we can share our ideas" (Aslı, Interview 1)

Aslı's group members shared the same ideas with her. Meryem implied importance of her group. With the group, she said that she learned effectively. Ece stated that in the group they had chance to try a lot. In these tries they learned easily. Namely in the group learning was a natural event according to Ece and she added that working in a group was enjoyable for her. In Group B's works sharing ideas came forward. For example Meryem stated a part from their study in the course:

> 'I sat between Aslı and Ece. Ece was using computer. We discussed in the group and we showed Ece what to do. We shared ideas in the group. Ece applied what we discussed…' (Meryem, Interview 1)

My field notes supported Meryem's words. In Group B's studies discussion is an ordinary event. One of field notes about their discussion was:

> 'They are discussing with each other. The focus of the discussion is design of their presentation with Tinkerplots... They opened a PowerPoint file and started to prepare their presentation…' (Field Note)

In Group B, all participants were happy about studying with the group and they benefitted from their group work for learning using educational program. They discussed and shared ideas in studying with the group. As they stated in the interviews, they asked each other about using programs properly. Therefore I concluded that studying with the group supported their TK development firstly. TK development had potential contributions to their development in other components of TPACK framework.

Contribution of group to the individual was another subcategory of group individual interaction category. In Group B, the group had an effect on participants' development in components of TPACK framework according to results of this study.

I will mention about contribution of the group to participants' development in components of TPACK framework with some cases based on interviews and field notes. According to my field notes Meryem did not attend some classes of the course in which Tinkerplots was studied. However in the Tinkerplots presentation she used computer. It was interesting for me because she did not attend the Tinkerplots classes because of her illness and she could use Tinkerplots in the presentation. I asked about her learning process, she answered:

> 'Learning process was enjoyable for me. I like challenges. Therefore in learning process I was irritated when I could not do but when I could do I became happy. At the beginning Ece and Aslı helped me a lot. They showed me how to use codes in Tinkerplots…' (Meryem, Interview 2)

In her words, I clearly concluded that group contributed in her learning in the course. My field notes supported Meryem's words about Ece and Aslı. I observed that they taught her using Tinkerplots in the first Tinkerpots course that Meryem attended after her illness. They showed basic options such as constructing graphs and tried to answer her questions. My observations and interviews showed me that she increased her knowledge to use Tinkerplots with the help of her group. Group's contribution was not for only Meryem's development in components of TPACK framework but also other members benefited from the group. For example in the first presentation Group B presented reflection and rotation with GeoGebra. Aslı stated that this topic was taught by Ece to the group. Therefore the group contributed their CK development. Then they discussed on this topic and decided to present it with GeoGebra. The group had a contribution for participants' learning of topics in mathematics and then related them with educational programs. Therefore I concluded that the group had contribution in their TCK development. Ece indicated about contribution of the group to her:

> ‘In the group, there may be many good ideas. I like studying with the group. I can see my mistakes easily within the group. When I am alone, I cannot see my mistakes and I cannot continue my study. Therefore I cannot improve something original.’ (Ece, Interview 1)

For Ece her group contributed her in being aware of her mistakes and fixing them to produce original studies. To sum up, all participants were happy with studying within a group because the group contributed their development in components of TPACK framework throughout the course.

In Group B participants’ development in components of TPACK framework was affected by intra-group dynamics. Intra-group dynamic are Views about Group Members, Rapport in the Group, and Role of a Particular Member.

In Group B, participants shared positive views about group members. Ece, Aslı and Meryem did not share any negative ideas about each other in the interviews. Aslı said that Ece was finding ideas for the group in their GeoGebra presentation process. Meryem stated that Ece and Aslı were hardworking people.

Group B, there was rapport among group members. They were satisfied with each other and they could study in a harmony in the group. My observations reflected signs of this harmony. This was one part of their study in Tinkerplots that showed this group’s harmony. “They discussed about data sets topic. They made a search. Then Aslı found a data set. They decided to use it. Meryem helped Aslı about coping data set from Excel to Tinkerplots. Ece took the control of the computer. Aslı and Meryem followed her work. Moreover they helped her” (Field Note). When they studied with one computer, the one who got control of the computer was not important for them. Each member could get the control in the group from time to time and others supported her by giving ideas. This was a result of their similar characteristics. Ece implied this as:

> ‘We like difficult works. All of us have this. We study together. All of us do not escape from work. We want to do our best in our studies. In Cabri 3D presentation, there were very simple choices that could be prepared in two hours. However we would not be satisfied with them. We wanted to do different and good thing. We wanted an attractive work…’ (Ece, Interview 3)

Their similar characteristic was enjoying difficult works. This was the reason behind working in a harmony in the group and developing rapport in the group. This was not only idea of Ece. Other group members shared same ideas with Ece. Meryem said that:

> ‘Group work is very useful if members in the group can get along. Last year Aslı was not here. We were doing homework together with Ece. I have many good friends in university. However if the situation requires studying, my friends change. I cannot study in a group with my best friends but I can study well with Ece and Aslı in a group. Ece and Aslı try to do their best in the group. I am like them. If we do something, it must be best. We do not like wasting our time. Group work is good for us because we have similar characteristics.’ (Meryem, Interview 1)

As Meryem clearly mentioned, group members had similar characteristics which made them a well-performing group. They had similar points of view about studying. Moreover they had rapport in the group. I concluded that this rapport among group members supported their development in components of TPACK framework because the group work was a part of the course. They had to study together. Members in Group B did this study in a harmony. They tried to learn using programs and developed their TK as a group. In the process of presentations they studied mathematical contents with educational programs, they prepared teaching and learning activities by using those programs and they made presentations by using educational programs. In all this processes rapport in the group made their work easier and it supported their development in components of TPACK framework.

In Group B, name of a particular member did not come forward. The reason behind this was rapport in the group. They studied in a harmony. Each member tried

to contribute group's studies. If there was something to do they did it together. Therefore a particular member did not have particular role.

Group B's results under Structure of the Course Theme

According to results of this study Structure of the Course is a Theme that affected pre-service teachers' development in components of TPACK framework. There are two categories under Structure of the Course Theme. These are content of the course and the instructor.

Content of the Course affected participants' development in components of TPACK framework. I will present content of the course under two subcategories. They are learning about educational programs and presentations.

In the course, participants' views on educational programs, experiences with educational programs, and applications in the course affected their development in components of TPACK framework according to Group B's results.

In the course, participants studied with three educational programs; GeoGebra, Tinkerplots, and Cabri 3D. I will state their views on them one by one.

In Group B, participants liked GeoGebra. They thought that GeoGebra was useful educational program for teaching geometry. They stated that a teacher could design many geometry lessons with GeoGebra. They implied that GeoGebra was proper for many geometrical topics of primary education. Moreover use of GeoGebra was not so complicated for primary education students. Therefore a mathematics teacher could easily integrate GeoGebra in classroom. They frequently appreciated GeoGebra in their interviews. All participants mentioned that they thought to use

GeoGebra when they become teachers and Meryem implied that GeoGebra supported constructivist point of view. She stated:

> 'GeoGebra is constructivist because there is nothing and you have to construct it. You can only see data clearly. You can construct…' (Meryem, Interview 2)

Aslı's point of view about GeoGebra was interesting. She said that:

> 'We write a sequent. We think on it. How can we write? We try. It does not happen. We try again. We must always think. We must write again and again. When I write and find I become very happy. Or when I cannot find, I learn by asking. Then I become happy. I like GeoGebra a lot. I like writing input.' (Aslı, Interview 2)

Aslı had positive views on GeoGebra because she liked thinking in using GeoGebra. Moreover Aslı stated that supporting teaching with GeoGebra was effective. In Group B, Gamze also liked GeoGebra and she established a relation between GeoGebra and Geometer's Sketchpad (GSP). She stated that:

> 'GeoGebra is similar with GSP. GSP was a basic program. GeoGebra was like it but GeoGebra is more developed…' (Ece, Interview 2)

In this group, all participants stated negative views about Tinkerplots. There were some reasons behind their views. First reason was "Tinkerplots is complicated for students" (Ece, Interview 2). Therefore, "it is difficult to use in classroom" (Meryem, Interview 2)."Students may get confused" (Meryem, Interview 2). According to my observations, Group B improved a solution about this complication of using Tinkerplots in primary education. They mentioned that "if we can reduce the number of data set and we can find more interesting data sets for primary education students" (Field Note). Namely they were intellectually active during the learning process of Tinkerplots because they were aware of potential problems and they tried to find solutions during the course. This effort was an example of use of their TPK. They tried to make Tinkerplots an effective teaching environment for students in

primary education. Second reason was “Tinkerplots is a limited program. Number of topics that can be studied is limited” (Aslı, Interview 2).“Probability and statistics are the topic that can be taught with Tinkerplots” (Ece, Interview 2). Tinkerplots was a limited program in terms of number of mathematical contents that could be taught by using Tinkerplots as participants in Group B stated. However they were aware of for which topics Tinkerplots was suitable. They could distinguish mathematical contents for teaching with Tinkerplots. This was an evidence of their TCK.

In Group B, all participants stated positive views about Cabri 3D. They liked using Cabri 3D. Meryem mentioned that teachers needed materials in teaching three dimensional objects and Cabri 3D provided all three dimensional objects samples and she added that learning three dimensional objects was not easy for students because they were abstract and difficult to imagine. Cabri 3D was useful to concrete three dimensional objects. Although Aslı liked Cabri 3D she added that she needed studying more in Cabri 3D:

> ‘Cabri 3D is an effective program but I must study it a lot to present it. Firstly I must be proficient. I need time to be proficient…’ (Aslı, Interview 3)

Participants’ difficulties with educational programs gave signs about their learning process in the course. In Group B, participants did not state about their difficulties with GeoGebra and Cabri 3D. They just shared their difficulties with Tinkerplots. At the beginning of the Tinkerplots classes they planned to present the difference between bar graph and histogram. However they could not draw a histogram with Tinkerplots. They just constructed bar graph and they also had difficulty in bar graph. Meryem clearly stated their experiences with Tinkerplots:

> ‘It is very difficult to understand rationale behind the program. It is too complicated. You cannot do anything with memorizing. You must learn rationale behind the program. We could not understand it. We did bar graph.

> Bar graph is formed by putting small data over and over. At the beginning data did not increase respectively. It was increasing complicated. There was a visually pollution on the screen. To solve it, we had to make a change in the program…' (Meryem, Interview 2)

Meryem's words showed me that when participants face with a difficulty in using a program, they tried to find a solution to it. Their difficulties were shaped around making some formations in programs and process of finding solutions to those difficulties had an effect on their TK development according to my conclusions.

According to results of this study applications in the course had contributions to participants' development in some components of TPACK framework. In interviews participants often indicated applications in the course. Their examples were related to applications in the course. I concluded that participants did not like Tinkerplots much and they faced difficulty with Tinkerplots. However they developed their knowledge in Tinkerplots and they could show their knowledge around Tinkerplots application in the course. Aslı stated that:

> 'We did an example in the course. For example we will write the word of ANNE. The probability of A is higher. We put other letters among them. Then we check for probabilities of letters…' (Aslı, Interview 2)

Ece implied one of applications in the course that was designed to define different quadrilaterals in GeoGebra. She said that she liked this application. She thought that it was an effective way of studying quadrilaterals. I concluded that applications in the course were important for participants' TK and TCK development. In applications they had chance to experience different functions of educational programs and this supported their TPACK development. In those applications they realized using educational programs for different mathematical contents and this supported their TCK.

For Group B preparing presentations, making presentation and other groups' presentations had roles in their development in components of TPACK framework according to results of this study.

In Group B, preparing presentation was the most commented part of presentations. I concluded that preparing presentations had a crucial role on TPACK development for participants in this group. Meryem stated that:

> 'When I study with programs, I found many lesson plans in English. I looked into them. I think that preparing presentation process brought in me many things…' (Meryem, Interview 3)

According to Meryem words, preparing presentation was also a process of searching about educational program and its using for teaching. In this process they went on improving their knowledge. All participants suffered from limited time for Cabri 3D. However in their presentation they presented visual representation of a^3-b^3. Aslı stated that:

> 'We did not see Cabri 3D enough. In the course, we could not be proficient in the program. We learned it in preparing our presentation' (Aslı, Interview 3)

The results showed me that preparing presentations made them mentally active about using educational programs. Moreover they had to improve something in mathematics by using educational programs. In this process they tried to answer the question of how students learn because Meryem implied that she studied on prepared lesson plans that were included educational programs. All these processes included different components of TPACK framework and I concluded that preparing presentations had an influence on participants' development in components of TPACK framework.

> 'Making presentation was good. We had a chance to apply what we learned. Though its preparation take much time, it is useful.' (Ece, Interview 3)

As Ece stated making presentation was useful for them. Aslı also implied the importance of making presentations. She gave examples from their GeoGebra presentation. She thought that she learned from that presentation. According to my observations, Group B's presentations sustained their learning of using given program for educational purposes. For example in GeoGebra presentation they created a real classroom setting. Meryem acted as a teacher and other acted as students. "Meryem taught by using discussion as a technique. She asked questions to her students. She gave chance them to construct a triangle and rotate it around the origin. At the end they discussed what they learned" (Field Note). Group B's presentations enabled them to test given educational program because of micro-teaching environment that they formed. The setting of the presentation was a model of a real classroom environment. In the presentations they acted as a teacher, they tried to teach specific mathematical contents by using educational programs. In such an environment they had to use their TPACK to make a presentation. Therefore I concluded that making presentation affected their TPACK development throughout the course.

In this group only Ece stated about other groups presentations. She especially implied that other groups' Tinkerplots presentations were successful. She thought that other groups' presentations could be a good resource for her. She indicated that:

> 'I think to use all presentations here in the future. They are in Dropbox. I will examine them. I will benefit from them in the future.' (Ece, Interview 3)

I concluded that Ece gave importance to other groups' presentations because of their potential to be resources for her in the future. However this did not show me that other groups' presentations had a role on participants' development in components of

TPACK framework. According to my observations, participants in Group B did not participate in discussions that were done after group presentations.

The instructor was a category under Structure of the Course Theme. The Instructor of the course had an important role in participants' TK development. They needed the instructor's support in the course and outside of the course. According to results of Group B, participants state that in the course the instructor is too busy but outside the course he tries to support participants.

All participants in Group B needed the support of the instructor to ask their questions. However they could not do this from time to time because the instructor was too busy in the class. One of my field notes related to this point was: "The group is waiting for 15 minutes to ask a question to the instructor. The instructor gives at least five minutes for a group" (Field Notes). Therefore participants advised an assistant for the course. Meryem stated that:

> 'An assistant is needed. The instructor is not enough for all. He cares everyone but he cannot answer everyone. I think he needs an assistant' (Meryem, Interview 1)

When participants could take necessary answers, they lost their focus in the class. Meryem explained it clearly:

> 'In the course, it is very bad not to get answer. It is an important problem of the course. We must get instant answers to our questions. If we do not get answer, we are entering facebook and twitter. If we face with something unknown, we become bored…' (Meryem, Interview 3)

In Group B, all participants had similar ideas with Meryem. They stated that in the class, the instructor's support was crucial for them. In using program, they deal with problems. Sometimes they could find solutions and they needed to ask the instructor. However according to my observations the instructor was very active about giving answers to students' questions. He not only gave answers but also asked questions to

the groups. For Group B, I observed that they took help of the instructor many times in the course but from time to time they waited much time. Moreover they underlined need of reaching to the instructor in the course. Therefore I concluded that the instructor has an important role for participants learning.

In Group B, all participants stated that they got the instructor's support outside the class. The instructor was available for them. In preparation of Cabri 3D presentation, they sent many e-mails to the instructor at night and they said that they took answers to their e-mails. In those e-mails they asked about how to do some constructions in Cabri 3D. All participants were enjoyable for this support because they stated that they could not make something without the instructor's support.

According to these results, participants in Group B needed the instructor's support to resolve their problems in using programs. Namely whenever their TK was not sufficient to do something in programs, they requested the instructor's support. Therefore I concluded that the instructor had an important role in participants' TK development throughout the course.

Third interview included questions number 8, 9, 10, and 11 (see Appendix D). These questions were different from other questions in interviews because they were directly related to mathematical content area. The aim of using these questions was to detect whether they could give different results from other questions. However after analysis of qualitative data, it was seen that data coming from these questions gave same results with other questions in the interviews. In other words, participants' responses to these questions did provide any systematically different findings regarding their TPACK development in the analysis process.

CHAPTER 5

CONCLUSIONS & RECOMMENDATIONS

The overall aim of this research was to advance an understanding of pre-service mathematics teachers' development in components of TPACK framework. The study was conducted within the context of a computer assisted mathematics instruction course and the participants of the study were pre-service mathematics teachers. The specific research questions were:

1. Is there a difference between pre-service teachers' pre-test and post-test scores of components of TPACK framework in a computer assisted mathematics instruction course?
2. How do pre-service mathematics teachers' components of TPACK framework develop during the computer assisted mathematics instruction course?

This section will review research questions above in terms of findings of this study. The previous chapter -Results- was a detailed representation of findings. In this section findings will be summarized, and conclusions will be offered based on findings. Recommendations for future research and limitations of this study will be discussed at the end of this section.

Summary of findings and conclusions

Research Question 1: Is there a difference between pre-service teachers' pre-test and post-test scores of components of TPACK framework in a computer assisted mathematics instruction course?

This research question formed the quantitative part of this study. TPACK Survey (Şahin, 2011) was used to identify the effect of the computer assisted mathematics instruction course on pre-service mathematics teachers' development in components of TPACK framework. Components of TPACK framework were PK, CK, TK, PCK, TPK, TCK, and TPACK. According to results coming from TPACK Survey (Şahin, 2011), for all components of TPACK framework, there is an increase in post-test scores compared to pre-test scores and this difference is statistically significant. However it cannot be claimed that only the course affected participants' development in PK, CK, and PCK. Participants took other courses related to mathematics education throughout the semester. Therefore those courses may have an effect on their PK, CK, and PCK developments throughout the semester. According to Angeli (2005), it is not an easy process to learn teaching with technology for pre-service teachers and it requires many efforts during their education. This can be accomplished by having technology related courses in the curriculum of the program (Angeli, 2005; Blankson et al.; 2010). This means that pre-service teachers are required to get courses that will enable them to gain knowledge about using technology for teaching. In this study, computer assisted mathematics instruction course was the only course related to technology that pre-service mathematics teachers taken in the term Therefore it can be concluded from

findings of this research that computer assisted mathematics instruction course has an effect on pre-service mathematics teachers' TK, TPK, TCK, and TPACK developments. This conclusion was consistent with other researches' findings in the literature that are related teachers' TPACK development. In Mouza's (2011) study teachers gained an increase in their TPACK, TK and TPK. In Polly's (2011) study teachers increased their TK. In their studies they used qualitative data to identify teachers' TK, TPK, and TPACK developments and they studied with teachers. In the current study pre-service teachers' TCK developed in addition to TK, TPK, and TPACK. However there are some differences between Mouza's (2011) and Polly's (2011) studies and the current study. First of all, they used qualitative data to identify TK, TPK, TCK, and TPACK developments. In the current study quantitative data was used to make such identification and qualitative data was used to explore reasons and mechanisms behind these developments. Secondly they collected data from practicing teachers but in the current study data were collected from pre-service teachers. Therefore this study showed that it is possible for pre-service teacher to gain components of TPACK framework within teacher education programs before being practicing teachers.

In the current study quantitative data was collected by TPACK survey from only one content area: mathematics as Schmidt et al. (2009) suggested. Results from TPACK survey showed that pre-service mathematics teachers' all components of TPACK framework developed throughout the course. However it was concluded that mainly pre-service mathematics teachers' TK, TPK, TCK, and TPACK developments can be attributed to taking the computer assisted mathematics instruction course and their experiences within the course.

Research Question 2: How do pre-service mathematics teachers' components of TPACK framework develop during the computer assisted mathematics instruction course?

In order to answer this research question, qualitative part of the study was designed. Six participants were observed throughout the course and three interviews were conducted with each participant. Those participants studied in two groups - Group A and Group B - throughout the semester. Group A was heterogeneous in terms of pre-test scores in TPACK survey, whereas Group B was homogeneous. Data coming from interviews and field notes were analyzed to explore how participants' components of TPACK framework developed during the course. Results were grouped under four themes: Technology, Personal Factors, Group Work, and Structure of the Course. In the Table 12, four themes and their categories and subcategories are shown. In the results part, findings of this study were given with respect to themes, categories and subcategories for each group separately. In this part how participants' TK, TPK, TCK, and TPACK developed during the course will be discussed one by one.

TK is a prerequisite for other forms of knowledge. Without basic skills of using technology it is not possible to integrate technology into teaching in a meaningful way (Graham et al., 2009). In the literature many researchers indicated the importance of having adequate TK for a teacher to integrate technology into education and lack of TK was seen as a barrier for technology integration process (Becker, 2000; Dockstader, 1999; Gorder, 2008; Hadley & Sheingold, 1993; Hardy 2008; Keengwe & Onchwari, 2011; Koehler & Mishra, 2005; Strudler et al., 1996; Wachira & Keengwe, 2010).

In this study all participants developed their TK throughout the course. This was an expected result for this study because participants met with three educational programs in the course and they used them to prepare presentations. Their TK development affected by all themes: Technology, Personal Factors, Group Work, and Structure of the Course. Under Technology Theme, having positive technology overviews and giving roles to technology in education process affected participants TK development. Personal Factors were affected participants' TK development. For example, in Group A, Berk's personal characteristics such as self-confidence to use technology supported his TK development. In Group B, Meryem's personal effort to use given educational programs affected her TK development. According to findings of this study Group Work Theme's effect on participants' TK development occurred in different ways. In Group B, all participants took advantage of group dynamics and they studied in harmony throughout the course and all of them developed their TK because of studying collaboratively. However in Group A, participants' TK developments occurred individually. For example, Berk had negative views about his group members' capabilities about using technology and he tried to do many works of the group individually. Moreover in this process he learnt how to use educational program and developed his TK.

In Group A, participants' TK developed but this was not a result of their collaboration in the group. Their TK development was not affected positively from their Group Work because of disharmony among group members in Group A. According to findings of this study it can be concluded that collaborative Group Work has either a positive or negative effect on pre-service mathematic teachers TK development within a computer assisted mathematics instruction course and this conclusion is consistent with other studies that imply the importance of collaboration

among pre-service teachers in a technology related course (Blankson et al., 2010; Kay, 2007; Maeng et al. 2013; Özen, 2013).

Table12.*Summary of Themes, Categories, and Subcategories*

TECHNOLOGY THEME Technology Overview Technology in Education Technology in Teaching Process Technology in Learning Process	PERSONAL FACTORS THEME Personal Effort Curiosity Experience Using What is Learned Personal Characteristic Views about the Course
GROUP WORK THEME Group-Individual Interaction Studying with the Group Contribution of Group to the Individual Intra-Group Dynamics Views about Group Members Rapport in the Group Role of a Particular Member	STRUCTURE OF THE COURSE THEME Content of the Course Learning about Educational Programs Views on educational programs Experiences with educational programs Applications in the course The Presentations Preparing presentations Making presentation Watching other groups' presentations The Instructor

Structure of the Course Theme was the last factor that affected participants' TK development. Content of the course and the instructor enabled participants to get

adequate TK to use given educational program. According to content of the course participants learned three educational program and prepared presentations for each program. In this content they had to develop their TK and whenever they faced a problem in using educational program, they got the help of the instructor. Therefore it can be claimed that the structure of the course was proper for pre-service teachers to get adequate TK as it was emphasized in the literature (Blankson et al., 2010).

According to findings of this study, participants' TPK developments occurred under technology in education category of Technology Theme for both groups. Technology in education category had two subcategories: technology in teaching process and technology in learning process. Participants gave new roles to teachers in teaching process by using technology. They were aware of being responsible to have pedagogical skills to teach with technology and this was consistent with Blankson et al.'s findings (2010). Participants tried to make reflections about how students learn better by using technology. Namely they related given educational programs with students' learning. As a conclusion of this study, pre-service mathematics teachers' TPK developments occurred around subcategories of technology in teaching process and technology in learning process. I think that this was an inevitable conclusion of this study because in the literature TPK was defined as the knowledge of effects of technology in teaching and learning processes and pedagogical strategies (Koehler & Mishra, 2009). Other findings of this study about TPK development occurred under Group Work Theme, Personal Factors Theme and Structure of the Course Theme. In Group A, Group Work had a role on Berk's TPK development. Under Group Work Theme there was a category of intra group dynamics. Role of a particular member, one subcategory of intra group dynamics, occurred in results of Group A. Berk was responsible for many works of the group and this made him mentally active about

use of educational programs with proper pedagogical strategies. In Group B, experience category of Personal Factors Theme affected Aslı's and Meryem's TPK developments. Their personal experiences supplied them knowledge about how students learn and they connected their existing knowledge with information coming from the course. Aslı and Meryem developed their knowledge around how students learn with given educational program and they developed their TPK throughout the course. Therefore it can be concluded that experiences of pre-service teachers have a potential to affect their TPK developments. This conclusion is consistent with other studies that see lack of experience as a barrier for teachers in technology integration process (Becker, 2000; Cox et al., 1999; Fullan, 1991; Hadley & Sheingold, 1993). View on educational programs was a subcategory of Structure of Course Theme. Participants in Group B implied that Tinkerplots was a complicated program for primary education students. They had such a view about the program. Therefore they tried to produce apprehensible activities with Tinkerplots to make Tinkerplots an effective teaching environment for students in primary education. This indicated their TPK development in the course which gave similar result with Koehler & Mishra (2009).

Findings of this study showed that participants could relate educational programs with mathematical contents and they could use educational programs for different mathematical subject matters. This indicated that their TCK development as stated in the literature (Koehler & Mishra, 2009). Findings of this study pointed that participants' TCK developments were affected by their Technology Overviews, Group Works, Personal Factors, and Structure of the Course. Participants' Technology Overviews that occurred in technology in teaching process subcategory indicated their TCK developments. However it was concluded that in Group A, one

participant, Emine did not show her TCK development because she thought that technology did not have an essential relation with mathematical contents. According to TPACK Survey pre-test and post-test scores of Emine it was seen that her overall TPACK scores decreased throughout the semester. This showed that technology in teaching process had a role on participants' TCK occurrence and development. In Group B, Berk was the one who was active in Group Work. As discussed before, his role in the group enforced him to make development in components in TPACK framework and his TCK development was affected by his position in the Group Work. However in Group B, all participants made use of advantage of group dynamics. Their results showed that in the process of CK and TK combination, they supported each other. All participants' TCK developments occurred in Group Work processes. Moreover in Group B, some personal factors such as curiosity, personal characteristics, and views about the course affected their TCK developments. Participants underlined that in the course, they had chances to refresh their knowledge on mathematical contents. In the process of using given educational programs, participants used and refreshed their knowledge about mathematical contents. According to findings of this study, Structure of the Course helped Berk's and Group B's participants of TCK developments. As stated in the result part, Berk was the one who prepared all presentations for Group A and in this process he developed his TCK. In Group B there was collaboration in benefiting from Structure of the Course such as learning educational programs to develop TCK. According to conclusions from these findings pre-service mathematic teachers' TCK development is dependent on the structure of the course to be content specific. Since the course was content specific, pre-service mathematics teachers had chance to relate given technology with their content area easily. This conclusion is parallel by other studies

in the literature (Gomez et al., 2008; Wachira & Keengwe, 2010). Another conclusion of this study is that there is a need of collaboration among group members for development of TCK and this is consistent with other studies in the literature (Blankson et al., 2010; Kay, 2007; Maeng et al. 2013; Ozen, 2013). An unexpected finding of this study was in Group A, one member's TCK decreased throughout the course because of her negative views on technology's relations with mathematical contents. Therefore a different conclusion of this study is that it is important to form positive views on technology in education for pre-service teachers. Otherwise, for some cases, it is possible to see some decrease in pre-service teachers' TCK in a computer assisted mathematics instruction course.

TPACK was explained by Koehler and Mishra (2009) as "the basis of effective teaching with technology, requiring an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content" (p.66). According to findings of this study, in general pre-service teachers gained TPACK throughout the course. However when results coming from TPACK Survey was analyzed, it was seen that three pre-service teachers' overall TPACK scores decreased from pre-test to post-test. One of these pre-service teachers was Emine who was a member of Group A. When qualitative data were analyzed, it was concluded that Emine did not gain TPACK throughout the course. In Group A, Zeynep's TPACK development was a result of Structure of the Course. She developed her TPACK in the process of learning about educational programs. In Group A, Berk was the one who developed his TPACK throughout the course separately from his group members. In Group A, as stated in the results part, there was not rapport among group members and they did not study in harmony. Berk was the one who took many responsibilities in the group such as solving

technical problems, preparing presentations, and making presentation. In Group A's studies, Berk took over a personal role and his TPACK development was affected from this process according to findings of this study. Moreover his TPACK development was dependent on his Technology Views. He gave technology a crucial role in teaching process. He had some Personal Factors such as personal effort, curiosity, and using what is learned that enabled him to carry out his learning about educational programs and he developed his TPACK throughout the course. When results of Group B were analyzed, it was seen that all participants developed their TPACK in the course. In Group B, participants had positive views about each other; they studied in harmony in Group Works and supported each others' learning in the course. In all processes of the course they studied collaboratively and that was their difference from Group A. Each member of Group B developed their TPACK throughout the course because of this collaboration. In Group B, Aslı stated that she did not have interest in technology but at the end of the course she developed her TPACK because of her group member's support in their studies and she developed a positive view on using technology in teaching process throughout the course as Meryem and Ece did. In Group B, Meryem's Personal Factor of using what is learned supported her TPACK development. She was curious about using technology and she used educational programs in her private lessons which helped her to develop her TPACK. Structure of the Course included applications with educational programs, preparing presentations, and making presentations. All these factors affected participants of Group B's TPACK developments. Since they studied in harmony, all participants benefited from applications with educational programs, preparing presentations, and making presentations. In the literature, for teachers, having TPACK is seen as a necessity to integrate technology into education (Hofer &

Swan, 2006; Grandgenett, 2008; Groth et al., 2009; Koehler & Mishra, 2008; Mouza, 2011; Polly, 2011; Polly & Brantley-Dias, 2009; Özmantar et al., 2010). In this study it can be concluded that pre-service teachers gained TPACK in the computer assisted mathematics instruction course. One of the conclusions of this study is that collaboration among pre-service teachers has a positive effect on their TPACK development. If there is not collaboration among group members, some participants may also develop their TPACK but all group members might not succeed in gaining TPACK in the group. Namely according to findings of this study, collaboration among pre-service teachers has an important role on their TPACK development and this conclusion is consistent with other studies in the literature (Blankson et al., 2010; Gomez et al., 2008; Kay, 2007; Maeng et al., 2013, Özen, 2013). Another conclusion of this study is pre-service teachers who have positive technology overviews are more probable to develop their TPACK because they are already users of technology and they give a value to technology in education. This was a conclusion similar to that of Cox et al. (1999). However if there is harmony in the group, pre-service teachers who do not have interest in technology can change their overview about using technology in education throughout the course with the support of their group members. This conclusion shows that collaboration among pre-service teachers may have potential to change effects of other factors in TPACK development process. Last conclusion that can be drawn from the findings of this study is that personal factors are effective on pre-service teachers TPACK development. Pre-service teachers who are curious about using technology, who use personal effort to use educational programs outside the course, who use what was learned in the course are more likely to develop their TPACK throughout the course.

Implications and recommendations

In Turkey there is a systematic policy to integrate technology into education. This systematic policy is called FATIH Project. This project aims at establishing "smart classes" in all schools in Turkey. Those "smart classes" will be equipped with ICTs such as IWB, tablet PCs and internet. In the near future, teachers will be responsible to teach in those "smart classes". This will give new responsibilities to teachers because teaching with technology is a complex process (Koehler & Mishra, 2008) and teachers need content knowledge, technology experience and pedagogical skills (Blankson et al., 2010) to manage this complex process. Koehler and Mishra (2009) underline the same point by stating the importance of having TPACK for a teacher to integrate technology into education. In this study pre-service mathematics teachers' TPACK development was examined in a computer assisted mathematics instruction course. In this part, implications and recommendations for teacher training programs and for future studies will be stated based on conclusions of this study.

For teacher education programs, there are some recommendations based on this study. First of all structure of technology related courses is important for TPACK development of pre-service teachers. Such courses should include educational programs related to pre-service teachers' content areas. Namely technology courses are required to be content-specific. Content-specific technology courses include one content area such as mathematics and pre-service teachers have chances to practice with technology by focusing their content areas. According to conclusions of this study collaboration among group members and coming up with a product by using educational programs have roles on pre-service teachers' TPACK developments. Therefore a further implication of this study for teacher education programs is that pre-service teachers should be enabled to study collaboratively and

they must be active users of such programs. They are needed to produce teaching activities by using educational programs.

Besides, according to the conclusions of this study pre-service teachers are more probable to develop their TPACK if they experience using technology in teaching process. Results indicated that even limited teaching opportunities provided within the confines of a university classroom had influences on pre-service teachers' TPACK development. Therefore they should be provided more with the opportunity of teaching by using technology in real classroom settings within the practice teaching courses. Taking this point into consideration, giving practice teaching courses and technology related courses at the same semester can be beneficial for pre-service teachers.

Lastly, according to the conclusions of this study the instructors have important roles in pre-service teachers' TK developments as previously claimed by Kay (2007) and Gorder (2008). TK is a prerequisite for other forms of knowledge (Graham et al., 2009) so having appropriate TK is basic for pre-service teachers' TPACK development. In this study, it was concluded that instructor was too busy in the course and participants had complaints about this situation. Therefore in a technology related course, the instructor needs an assistant who can answer pre-service teachers' questions about using educational programs.

For future studies there are two recommendations of this study. Firstly, in this study, pre-service teachers were observed in the course and the focus of the study was their TPACK development. In future studies it would be a good idea to conduct research about how pre-service teachers use their TPACK in their practice teaching. Secondly for the future studies, I recommend to study with in-service teachers who

are new graduates. This may enable researchers to detect how in-service teachers use their TPACK and what are their inadequacies to integrate technology in education. Through such studies, more recommendations may be done for teacher training programs by investigating TPACK and TPACK-teaching interactions from the field.

Limitations

This study was conducted in a university's last year computer assisted mathematics instruction course. Quantitative data were collected from 29 pre-service mathematics teachers. Qualitative data were collected from 6 participants. The structure of the course included learning three educational programs, preparing and making presentations for each programs. The course was given in a computer laboratory. Participants studied in groups throughout the semester. The results coming from this study may have some limitations because of various factors that are specific for the current study. This study is limited with the university in which study was conducted. The group size was small in this study. This may be another limitation of this study. Participants studied with three educational programs throughout the course. The results coming from this study can be dependent on these three educational programs. The conclusions of this study may be limited with these educational programs or programs with similar features and requirements. In this study the researcher tried to explain results and conclusion in a detailed way and he tried to make justifications about his explanations and the qualitative part of this study included the researcher's explanations. Even though this is justified subjectivity, it can be considered as another limitation of conclusions of this study.

APPENDICES

Appendix A

ISTE Standards and Performance Indicators (2000, ISTE)

1. TECHNOLOGY OPERATIONS AND CONCEPTS

Teachers demonstrate a sound understanding of technology operations and concepts.

Teachers:

A. demonstrate introductory knowledge, skills, and understanding of concepts related to technology

B. demonstrate continual growth in technology knowledge and skills to stay abreast of current and emerging technologies.

2. PLANNING AND DESIGNING LEARNING ENVIRONMENTS AND EXPERIENCES

Teachers plan and design effective learning environments and experiences supported by

technology.

Teachers:

A. design developmentally appropriate learning opportunities that apply technology-enhanced

instructional strategies to support the diverse needs of learners.

B. apply current research on teaching and learning with technology when planning learning environments and experiences.

C. identify and locate technology resources and evaluate them for accuracy and suitability.

D. plan for the management of technology resources within the context of learning activities.

E. plan strategies to manage student learning in a technology-enhanced environment.

3. TEACHING, LEARNING, AND THE CURRICULUM

Teachers implement curriculum plans that include methods and strategies for applying technology to maximize student learning.

Teachers:

A. facilitate technology-enhanced experiences that address content standards and student technology standards.

B. use technology to support learner-centered strategies that address the diverse needs of students.

C. apply technology to develop students' higher order skills and creativity.

D. manage student learning activities in a technology-enhanced environment.

4. ASSESSMENT AND EVALUATION

Teachers apply technology to facilitate a variety of effective assessment and evaluation strategies.

Teachers:

A. apply technology in assessing student learning of subject matter using a variety of assessment techniques.

B. use technology resources to collect and analyze data, interpret results, and communicate findings to improve instructional practice and maximize student learning.

C. apply multiple methods of evaluation to determine students' appropriate use of technology resources for learning, communication, and productivity.

5. PRODUCTIVITY AND PROFESSIONAL PRACTICE

Teachers use technology to enhance their productivity and professional practice.

Teachers:

A. use technology resources to engage in ongoing professional development and lifelong learning.

B. continually evaluate and reflect on professional practice to make informed decisions regarding the use of technology in support of student learning.

C. apply technology to increase productivity.

D. use technology to communicate and collaborate with peers, parents, and the larger community in order to nurture student learning.

6. SOCIAL, ETHICAL, LEGAL, AND HUMAN ISSUES

Teachers understand the social, ethical, legal, and human issues surrounding the use of technology in PK–12 schools and apply that understanding in practice.

Teachers:

A. model and teach legal and ethical practice related to technology use.

B. apply technology resources to enable and empower learners with diverse backgrounds, characteristics, and abilities.

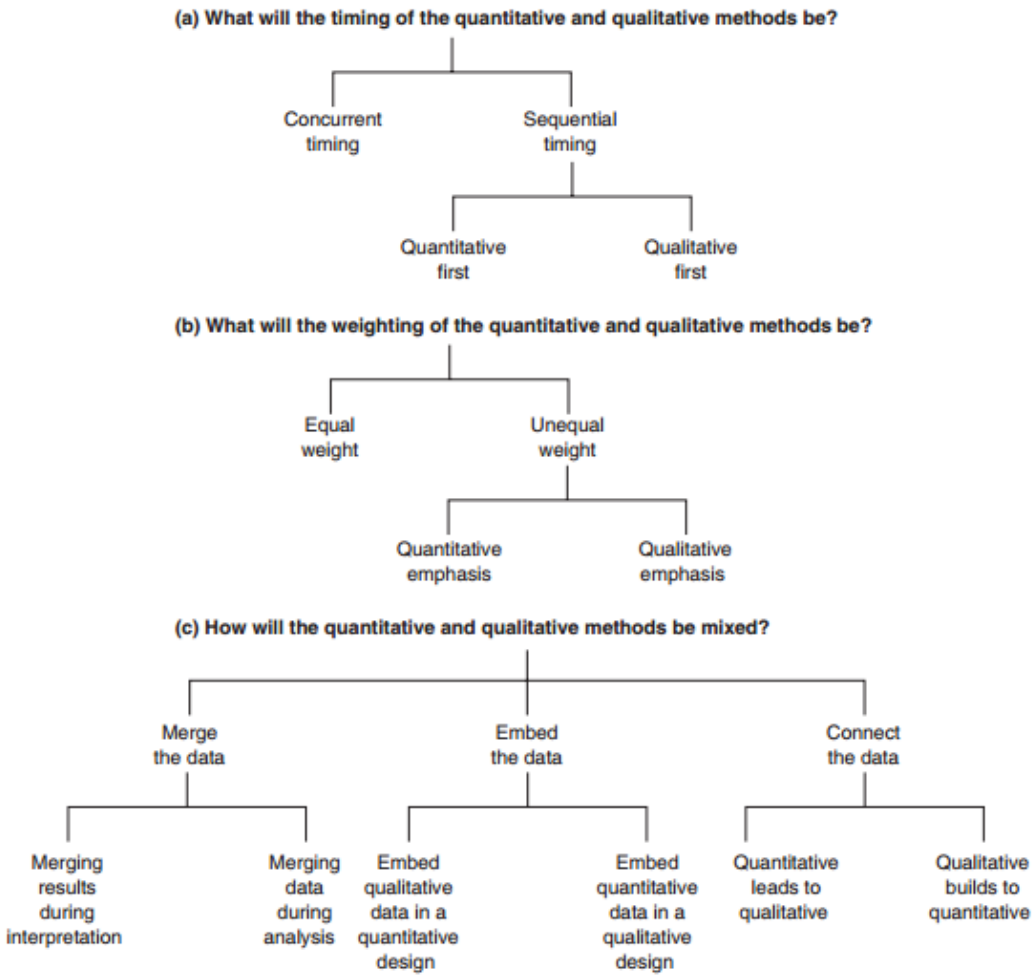
C. identify and use technology resources that affirm diversity.

D. promote safe and healthy use of technology resources.

E. facilitate equitable access to technology resources for all students.

Appendix B

Decision Tree for Mixed Methods Design



Appendix C

Öğretmen Adaylarının Teknolojik Pedagojik Alan Bilgisi (TPAB) Ölçeği

Boyut	Ölçek Maddeleri*
TB	Bilgisayarda çıkan teknik bir sorunu gidermeyi…
	Temel bilgisayar donanım parçalarını (CD-Rom, ana bellek, RAM gibi) ve işlevlerini…
	Temel bilgisayar yazılımlarını (Windows, Media Player) ve işlevlerini…
	Son çıkan bilgisayar teknolojilerini…
	Kelime işlemci programlarını (Word gibi) kullanmayı…
	Hesap tablosu programlarını (Excel gibi) kullanmayı…
	İnternet yoluyla (e-mail, MSN Messenger gibi) iletişim kurmayı…
	Resim programlarını (Paint gibi) kullanmayı…
	Sunum programlarını (Powerpoint gibi) kullanmayı…
	Veri kaydetmeyi (Flash Bellek, CD, DVD'ye kaydetmek gibi) …
	Bilim dalıma özgü programları kullanmayı…
	Yazıcı kullanmayı…
	Projektör kullanmayı…
	Tarayıcı kullanmayı…
	Dijital kamera kullanmayı…
PB	Öğrenci performansını değerlendirmeyi…
	Bireysel farklılıkları gidermeyi…
	Farklı değerlendirme yöntem ve tekniklerini…
	Farklı öğrenme teori ve kuramlarını (Yapısalcı Öğrenme, Çoklu Zekâ Teorisi, Proje-tabanlı Öğretim, gibi)…
	Karşılaşılabilecek öğrenci kavrama zorluk ve yanılgılarını…
	Sınıf yönetimini…
AB	Alanımdaki temel konuları…
	Dersim için sınıf etkinlik ve projeleri geliştirmeyi…
	Alanımdaki son gelişme ve uygulamaları…
	Alanımda öne çıkan kişileri…
	Alanımda çıkan güncel kaynakları (örneğin, yayın ve kitapları)…
	Alanımda düzenlenen konferans ve etkinlikleri…
TPB	Dersimde kullanacağım öğrenme/öğretme yaklaşımlarına/stratejilerine uygun teknolojileri…
	Öğrenmeyi olumlu yönde etkileyecek teknolojileri (bilgisayar uygulamalarını)…
	Öğretmenlik mesleğimde faydalı olabilecek teknolojileri ayırt etmeyi…
	Yeni bir teknolojinin eğitim-öğretime uygunluğunu değerlendirmeyi…
TAB	Alanıma özgü teknolojileri (bilgisayar uygulamalarını)…
	Öğretim planındaki belirtilen hedeflere daha kolay ulaşmayı sağlayacak teknolojileri…
	Öğretim teknolojilerinin kullanımını içeren bir ders planı hazırlamayı…
	Öğretim teknolojileri içeren sınıf etkinlik ve projeleri geliştirmeyi…
PAB	Dersime uygun etkili öğretim stratejilerini seçmeyi…
	Öğrencilerime dersimde uygulayacağım değerlendirme test ve ölçekleri geliştirmeyi…
	Sınıf/okul içi etkinlikleri içeren bir ders planını rahatlıkla hazırlayabilmeyi…
	Alanımda uygulanan öğretim planındaki belirtilen hedefleri (kazanımları)…
	Uygun konularda ders-içi ilişkilendirmeyi…
	Uygun konularda diğer derslerle ilişkilendirmeyi…
	Alanımdaki uygun konuları okul dışı etkinliklerle desteklemeyi…
TPAB	Ders içeriğini, uygun teknoloji ve öğretim ilke/yöntemleri ile bütünleştirmeyi…
	Konumu daha iyi öğretmemi sağlayan çağdaş teknoloji ve stratejileri seçmeyi…
	Alan, formasyon ve teknoloji bilgimi uygun bir şekilde bütünleştirerek ders anlatmayı…
	Meslektaşlarıma alan, formasyon ve teknoloji bilgisinin bütünleştirilmesi konusunda liderlik yapabilmeyi…
	Farklı öğretim strateji ve teknolojileri ile bir konuyu anlatabilmeyi…

* Ölçek seçenekleri: (1) Hiç bilmiyorum, (2) Az düzeyde biliyorum, (3) Orta düzeyde biliyorum, (4) İyi düzeyde biliyorum, (5) Çok iyi düzeyde biliyorum

Appendix D

1ST INTERVIEW QUESTIONS

1) How is your interest in technology? Which programs can you use? What are your aims to use that program?
2) Which courses that you took in university did increase your technology knowledge?
3) Do you think those courses will contribute your teaching when you become a mathematics teacher? In what ways will those courses contribute you? Do you think that you are capable of using these knowledge and skills in a classroom environment?
4) Is technology necessary in mathematics education? Why or why not?
5) What is the role of technology in mathematics education?
6) What does it mean to enrich mathematics class with technology?
7) What are the roles of teachers and students in a technology enriched mathematics classroom?
8) What are the difficulties that teachers will meet in a technology enriched mathematics classroom? What can be done to overcome these difficulties?
9) What are the educational programs that you can use? Can you use them in a real classroom setting?
10) Which contents of mathematics can be taught with these educational programs? How do these programs help teaching mathematical contents? Can you give examples?
11) What are the benefits of using those educational programs for teachers? How can you use these programs effectively in classroom activities?

2ND INTERVIEW QUESTIONS

1) Is technology education necessary for pre-service teachers in university? Should technology courses become in teacher education programs?
2) How do you explain a technology enriched mathematics lesson? What does make this lesson successful?
3) Can you draw a picture of a technology enriched classroom? What are equipments of this classroom? How do you design this classroom?
4) Would you want to share your experiences with GeoGebra? What did you present with GeoGebra? What was the grade level of this topic? What were the objectives about this topic that were stated in the curriculum? What are other topics in the curriculum that this topic is related?
5) What are the difficulties that you faced with while learning GeoGebra, you are preparing and doing your presentation?
6) Do you think to use GeoGebra when you become a teacher? Which topic can be taught by using GeoGebra?
7) Do you think that using GeoGebra is effective for teaching mathematics? Why or why not?
8) How do you organize your classroom environment when you use GeoGebra? How do maintain classroom management when you use GeoGebra? Which teaching methods do you use? What are the difficulties that you may face with?
9) Would you want to share your experiences with Tinkerplots? What did you present with Tinkerplots? What was the grade level of this topic? What were the objectives about this topic that were stated in the curriculum? What are other topics in the curriculum that this topic is related?

10) What are the difficulties that you faced with while are learning Tinkerplots, you are preparing your presentation and you are doing your presentation?
11) Do you think to use Tinkerplots when you become a teacher? Which topic can be taught by using Tinkerplots?
12) Do you think that using Tinkerplots is effective for teaching mathematics? Why or why not?
13) How do you organize your classroom environment when you use Tinkerplots? How do maintain classroom management when you use Tinkerplots? Which teaching methods do you use? What are the difficulties that you may face with?
14) What should be technological qualifications of a mathematics teacher according to you? What can s/he do by using technology? Do you think that you have these qualifications? What are the effects of the courses that you took in university on your technological qualifications about using technology in teaching process?

3RD INTERVIEW QUESTIONS

1) In this term you took a course about computer assisted mathematics education. What are the contributions of this course in terms of being a teacher?
    a) How does your technology knowledge change throughout the course?
    b) How does the course contribute to you in terms of teaching mathematics by using technology?
2) What could be different in the course to make the course more beneficial for you?

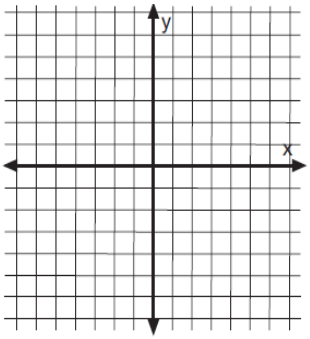
3) Can you share your experiences with Cabri 3D? What did you present with Cabri 3D? What was the grade level of this topic? What were the objectives about this topic that were stated in the curriculum? What are other topics in the curriculum that this topic is related?
4) What are the difficulties that you faced with while are learning Cabri 3D, you are preparing your presentation and you are doing your presentation?
5) Do you think to use Cabri 3D when you become a teacher? Which topic can be taught by using Cabri 3D?
6) Do you think that using Cabri 3D is effective for teaching mathematics? Why or why not?
7) How do you organize your classroom environment when you use Cabri 3D? How do maintain classroom management when you use Cabri 3D? Which teaching methods do you use? What are the difficulties that you may face with?
8) In the below there are some mathematical topics from 8th grade level curriculum. What is your order to teach these topics?
    - ✓ Reflection and rotation of geometrical objects
    - ✓ Probability
    - ✓ Relations among sides of Triangles
    - ✓ Polyhedral
    - ✓ Pyramids, Cone, and Sphere
    - ✓ Pythagoras Theorem
    - ✓ Intersections of polyhedral
    - ✓ Geometric objects and symmetry
    - ✓ Prisms

✓ Perspective

a) In which topics can you make computer assisted teaching?

b) What are the advantages of using technology to teach these topics?

9) Köşe noktalarının koordinatları A(-7,4), B(-7,1) ve C(-1,1) olan $\widehat{ABC}$'ni çiziniz. Aynı düzlemde köşe noktalarının koordinatları $\widehat{ABC}$'nin köşe noktalarının koordinatlarının (-1) ile çarpımına eşit olan $\widehat{A'B'C'}$'ni çiziniz. İki üçgen arasındaki ilişkiyi açıklayınız.



a) What is the relation between two triangles?

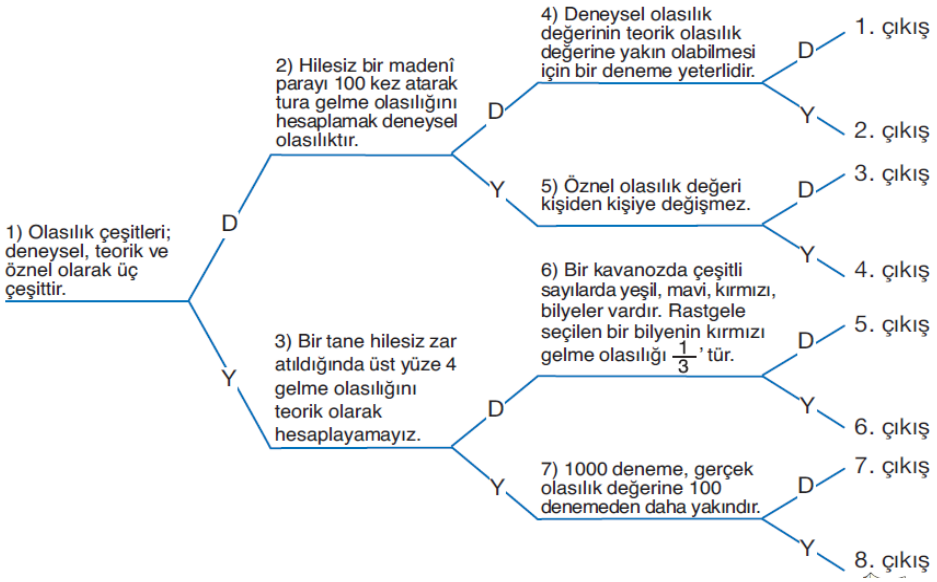
b) Do students face with difficulties while they are learning this topic?

c) How do support your students' learning as a teacher?

d) What are your techniques and strategies to teach this topic?

e) Which technological tools do use in teaching this topic? Why? What are the contributions of technological tools to teach this topic?

10) Aşağıda birbiriyle bağlantılı doğru / yanlış cümleler verilmiştir. Şemadaki cümlelerde doğru olduğu belirtilen yargı yanlış, yanlış olduğu belirtilen yargı doğru olabilir. Her bir doğru / yanlış kararı sizi farklı çıkışlara ulaştırır. Buna göre aşağıdaki çıkışlardan birine ulaşınız.



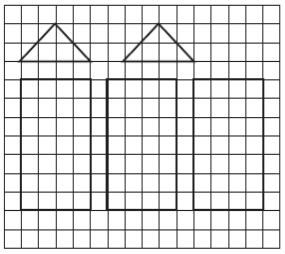
a) What is the solution?

b) Which technological tools do use in teaching this topic? Why? What are the contributions of technological tools to teach this topic?

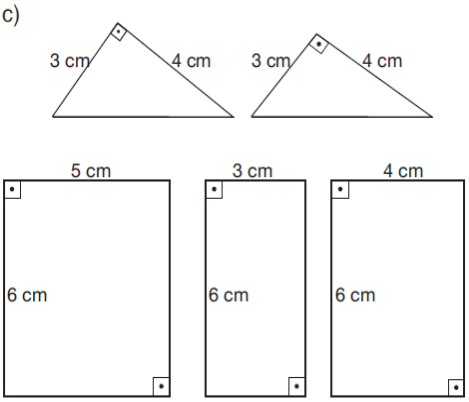
11) Aşağıda her bir seçenek için verilen çokgenlerle üçgen prizma oluşturulup oluşturulamayacağını belirleyiniz.

a)

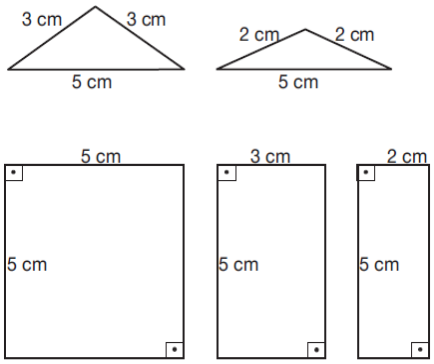
b)



c)



ç)



a) What is the solution?

b) What are the difficulties that students will face with while they are solving this question?

c) How do support your students' learning as a teacher?

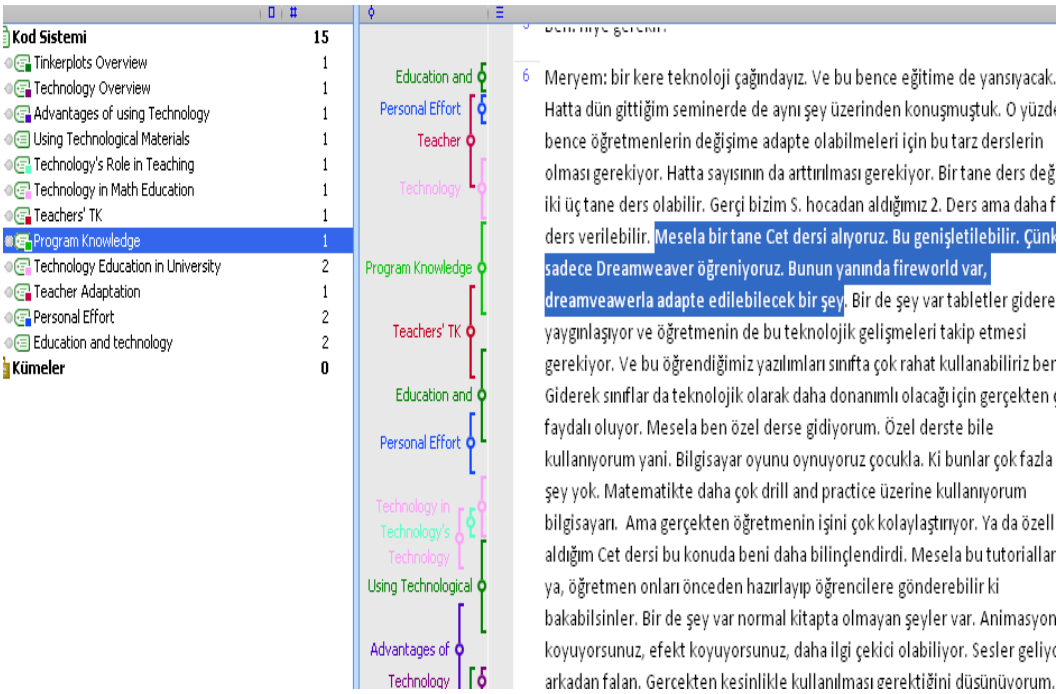
f) How do teach this topic in a real classroom setting? What are your techniques and strategies to teach this topic?

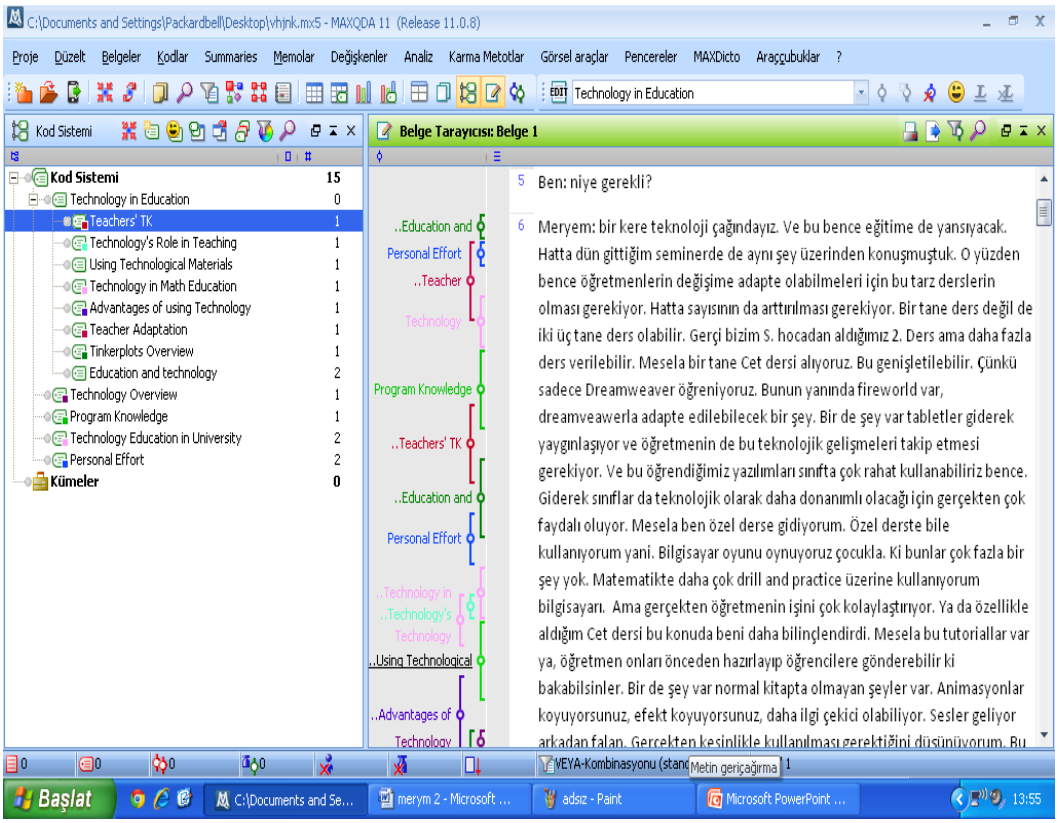
g) Which technological tools do use in teaching this topic? Why? What are the contributions of technological tools to teach this topic?

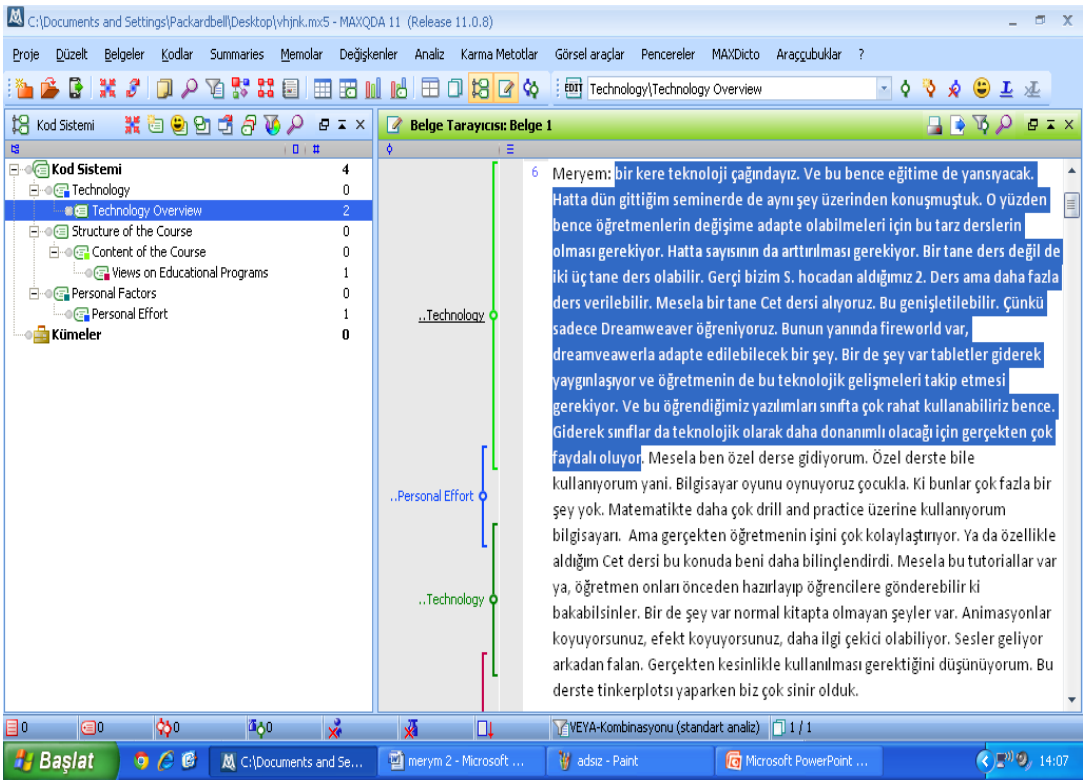
h) What are the contributions of using technological tools for students' learning?

Appendix E

Analysis Process of Qualitative Data



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Technology\Technology Overview
Kod Sistemi
Kod Sistemi 4
Technology 0
Technology Overview 2
Structure of the Course 0
Content of the Course 0
Views on Educational Programs 1
Personal Factors 0
Personal Effort 1
Kümeler 0
Belge Tarayıcısı: Belge 1
..Technology
..Personal Effort
..Technology
6 Meryem: bir kere teknoloji çağındayız. Ve bu bence eğitime de yansıyacak. Hatta dün gittiğim seminerde de aynı şey üzerinden konuşmuştuk. O yüzden bence öğretmenlerin değişime adapte olabilmeleri için bu tarz derslerin olması gerekiyor. Hatta sayısının da arttırılması gerekiyor. Bir tane ders değil de iki üç tane ders olabilir. Gerçi bizim S. hocadan aldığımız 2. Ders ama daha fazla ders verilebilir. Mesela bir tane Cet dersi alıyoruz. Bu genişletilebilir. Çünkü sadece Dreamweaver öğreniyoruz. Bunun yanında fireworld var, dreamveawerla adapte edilebilecek bir şey. Bir de şey var tabletler giderek yaygınlaşıyor ve öğretmenin de bu teknolojik gelişmeleri takip etmesi gerekiyor. Ve bu öğrendiğimiz yazılımları sınıfta çok rahat kullanabiliriz bence. Giderek sınıflar da teknolojik olarak daha donanımlı olacağı için gerçekten çok faydalı oluyor. Mesela ben özel derse gidiyorum. Özel derste bile kullanıyorum yani. Bilgisayar oyunu oynuyoruz çocukla. Ki bunlar çok fazla bir şey yok. Matematikte daha çok drill and practice üzerine kullanıyorum bilgisayarı. Ama gerçekten öğretmenin işini çok kolaylaştırıyor. Ya da özellikle aldığım Cet dersi bu konuda beni daha bilinçlendirdi. Mesela bu tutoriallar var ya, öğretmen onları önceden hazırlayıp öğrencilere gönderebilir ki bakabilsinler. Bir de şey var normal kitapta olmayan şeyler var. Animasyonlar koyuyorsunuz, efekt koyuyorsunuz, daha ilgi çekici olabiliyor. Sesler geliyor arkadan falan. Gerçekten kesinlikle kullanılması gerektiğini düşünüyorum. Bu derste tinkerplotsı yaparken biz çok sinir olduk.
VEYA-Kombinasyonu (standart analiz)
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