Examining Pre-Service Mathematics Teachers' Beliefs of TPACK during a Method Course and Field Experience

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ABSTRACT

The aim of this study is to investigate how and why elementary mathematics pre-service teachers' (PSTs) beliefs about TPACK changed during a method course and field experience. Six PSTs were selected purposefully with reference to their different technological and mathematical backgrounds. Participants were interviewed five times (beginning of the study, after workshops, after method course, beginning and end of field experience) and interviews were conducted within the context of Niess (2005)' TPACK components. Content analysis was performed with the help of a codebook developed by reviewing TPACK components literature. It has been seen that PSTs' had naïve beliefs at the beginning of the study. Workshops, method course and field experience seemed to change their beliefs. Management concerns began to affect beliefs when PSTs' experiences about teaching with technology increased. It was suggested to give more opportunities for PSTs to teach with technology because; it was found that experiences had the most effect on beliefs.

Keywords: technological pedagogical content knowledge (TPACK), pre service teachers, mathematics education, beliefs

INTRODUCTION

Rapidly changing and developing technological tools have affected the styles of learning and teaching mathematics (Heid, 2005; Isıksal & Askar, 2005; Kaput, 1992). In technology-rich classrooms, students can develop multiple representations (Heid, 2005), focus on conceptualizing, decision-making, reflecting, reasoning, and problem solving (Lee & Hollebrands, 2008; NCTM, 2000; Tall, 1998), and engage with activities with high motivation and explore mathematical ideas (Geiger, Forgasz, Tan, Calder, & Hill, 2012). But most of the teachers don't use technology to support student's learning as mentioned; instead they use technology for planning lesson, data storage, presentation, and finding online resources (Chen, 2010; Inan & Lowther, 2010). The main reason why they use technology in this manner is assumed as teachers didn't learn mathematics with technology (Niess, 2006). Even if they had experiences with teaching and learning mathematics with technology, especially experienced teachers may wonder about losing control in classrooms and may not need a change in their teaching professions (Pierce, Ball, & Stacey, 2009). Based on the development of technology, mathematics educators were supposed to study how technological tools can be used to support mathematical thinking (Niess, 2006). Researchers (Angeli & Valanides, 2005; Keating & Evens, 2001; Koehler & Mishra, 2005; Margerum-Leys & Marx, 2002; Niess, 2005) attempted to determine what teachers should know in order to use technology effectively. It was seen that the common idea was technology-supported pedagogical knowledge. The most known framework is the notion of TPACK developed by Koehler and Mishra (2005), which is used to define teacher knowledge needed for effective technology integration.

Many researches show that in/pre-service teachers' beliefs and experiences with technology play an important role on their decisions about use of technology (Cavin, 2007; Ertmer, Ottenbreit-Leftwich, &York, 2006; Larkin, Jamieson-Proctor, & Finger, 2012; Mudzimiri, 2012). Pre-service teachers' (PSTs') knowledge, beliefs, and attitudes will give information about how they will use technology in their future class (Abbitt, 2011). So determining what they know and think about teaching mathematics with technology can help teacher educators and administrators to design professional development programs that will prepare teachers so as to teach digital natives (Prensky, 2001) and will lead to belief change. It can be said that teacher beliefs may be more effective in teaching than teacher knowledge (Pajares, 1992). PSTs' beliefs and conceptions about teaching with technology affect to what extent they perceive and use instructional strategies in their teacher preparation programs (Tillema & Knoll, 1997). They bring personal beliefs about teaching style of a good teacher and thinking themselves as a teacher, and pupilage memories to teacher education programs. These existing beliefs need to be evolved and reconstructed to enable professional growth (Kagan, 1992).

Distinguishing beliefs and knowledge is difficult (Pajares, 1992). PSTs' beliefs about the nature of teaching with technology may contribute to teacher education programs to promote teacher knowledge and support conceptual change. Specifying the knowledge base that is to be considered is crucial in assessing PSTs' beliefs (Fives & Buehl, 2009). TPACK can be used as a knowledge base to understand what kind of beliefs about teaching mathematics with technology PSTs have. TPACK can be used to investigate PSTs' knowledge, beliefs, and reasoning during technology integration (Jones, 2012). Unpacking PSTs' beliefs of TPACK may be a guide to determine how they will organize and define technology-based mathematical tasks and problems (Pajares, 1992).

PSTs' reasoning and intentions about teaching with technology may be more obvious in their views than behaviors (Jones, 2012). PSTs with different mathematical and technological background were participated in this study. They were interviewed five times; at the beginning, after workshops, after method course, before and after field experience to examine how and why their beliefs about technology change. It is thought that determining the pattern and reason of belief change in PSTs' TPACK may contribute to enhance teacher knowledge needed for effective technology integration.

Technological Pedagogical Content Knowledge in Mathematics Education

Shulman's (1986) notion of Pedagogical Content Knowledge (PCK) includes using appropriate technologies in presenting concepts when teachers need (Cox & Graham, 2009). Ertmer and Ottenbreit-Leftwich (2010) argued that PCK definition let teachers to think they are good at teaching, even if neither they nor their students use technology. Koehler and Mishra (2008) suggested that knowledge of technology should be incorporated into PCK due to role of technology in society and rapid changes of technology. TPACK is the way of thinking about teacher knowledge to teach mathematics with appropriate technologies in constructive and effective ways.

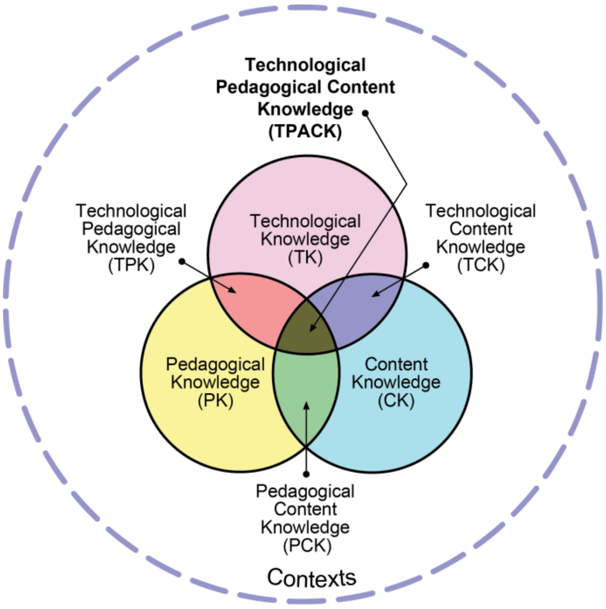

Figure 1. TPACK framework (Reproduced by permission of the publisher, © 2012 by tpack.org)

TPACK was developed by adding knowledge of technology to Shulman's idea of PCK. TPACK framework consists of seven knowledge bases; main components are knowledge of technology (TK), pedagogy (PK) and content (CK) and the intersections between these domains are Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), and intersection of these: Technological Pedagogical Content Knowledge (Figure 1). Technological pedagogical mathematical knowledge, knowledge need for teaching mathematics with technology, includes knowledge of mathematics content that students are expected to learn, knowledge of pedagogies related to mathematics content and knowledge of technology that provides using technology to support teaching and learning mathematics (Polly, 2014).

Niess (2013) discussed two perspectives about TPACK: *integrated* and *interdisciplinary. Interdisciplinary* perspective refers that all of the sub-domains (TK, PK, CK, TPK, TCK, PCK and TPACK) are considered independently. On the other hand *integrated* view emphasizes the transformation of all sub-domains into center intersection: TPACK. Niess (2013) identified this transformation as a chemical change in which the other knowledge bases are rearranged and integrated. However, Archambault and Barnett (2010) argued that distinguishing each of these domains is difficult. Niess (2013) identified four components of TPACK that is the center subset, extending Grossman's (1990) PCK components;

(i) *An overarching conception about the purposes for incorporating technology in teaching mathematics (purpose)*

(ii) *Knowledge of students' understandings, thinking, and learning in mathematics with technology (student)*

(iii) Knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics (

(iv) Knowledge of instructional strategies and representations for teaching and learning mathematics with technology

PSTs' beliefs and knowledge about TPACK components rely on their little experiences with accessing technology and they are also naïve and deficient (Niess, 2008). Teaching PSTs mathematics with technology is a way to improve PSTs' overarching conception of what it means to teach with technology (Niess, 2005). They should be given the opportunity to use appropriate technologies with students, employing curricular materials and instructional strategies that integrate technology into teaching and learning mathematics to develop their knowledge about instructional strategies and curricular materials. They also need these opportunities to interact with students and explore their thinking about mathematics in technology-rich classrooms.

Technology provides opportunities for students to visualize mathematics, engage with mathematics, verify conjectures and have positive attitudes about mathematics (Kersaint, 2007). Teachers of mathematics should possess TPACK to give their students these opportunities. TPACK requires planning, organizing, critiquing and abstracting mathematics with technology for specific students in a specific classroom situation (Niess, 2008). Most of the PSTs are not proficient in planning and implementing lessons with appropriate technologies in classrooms because they didn't learn mathematics in technology supported classrooms. Teachers of mathematics with strong TPACK (I) are open to new technologies and know that students can explore mathematical ideas with appropriate technologies; (ii) look for the ways of teaching mathematical concepts with technology; (iii) know what students know and learn, and how technology supports students; (iv) explain students why technology is used and what they will do with technology; and (v) adopt teaching with technology due to students' learning (Grandgenett, 2008).

Most of the studies examined PSTs' TPACK within the context of the courses (Larkin et al., 2012; Meagher Ozgun-Koca, & Edwards, 2011; Mudzimiri, 2012; Niess, 2005; Ozgun-Koca, Meagher, & Edwards, 2010), the professional development programs (Agyei & Voogt, 2012; Cavin, 2007), or the projects (Harrington, 2008; Lee & Hollebrands, 2008) that include planning and teaching technology-based mathematics lessons. Results show that PSTs made the most progress when they were demonstrated models of teaching with technology. Technology-enhanced method courses and field experience have an effect on especially PSTs' purpose, student and strategy components (Meagher et al., 2011).

Beliefs about Teaching with Technology and Belief Change

Teacher beliefs arise from their experiences related to themselves, instruction and mathematical knowledge (Richardson, 1996). PSTs have limited, formal, and robust beliefs about mathematics that are resistant to change (Larkin et al., 2012) and think that mathematics must be taught in the same way as they learnt. Their views may change slowly at best (Thompson, 1992). There is a relationship between PSTs' beliefs about technology use and beliefs about how mathematics should be taught. Teachers who have rule-based beliefs about mathematics cannot consider technology as a tool to improve or enhance instruction and would like to control students' use of technology (Tyminski, Haltiwanger, Zambak, Horton, & Hedetniemi, 2013). Teachers' resistant to change beliefs about technology is one of the reason that affect technology integration (Zelkowski, Gleason, Cox & Bismarck, 2013).

Meagher et al. (2011) grouped PSTs into three categories according to their beliefs about teaching with technology; *naysayers, yes-but,* and *yes-and*. In the first category, PSTs don't tend to use technology. *Yes-buts* emphasize firstly teaching concepts and then using technology while *yes-ands* consider technology as a learning tool. Most of PSTs learnt mathematics in traditional environments so they are mostly in the first and second category (Meagher et. al, 2011). In another study related to teachers' beliefs about teaching with technology, Hanzsek-Brill (1997) determined three positions of beliefs according to teachers' views about when technology should be used. These beliefs were labeled as *exploratory*, *post-mastery*, and *pre-mastery*. Teachers with exploratory beliefs think that students can explore mathematical concepts and procedures with technology. Post-mastery beliefs refer to using technology after mathematical concepts and procedures have been mastered by hand. Teachers with pre-mastery beliefs use technology rarely and minimally productively before their students have mastered mathematical concepts and procedures (Leatham, 2007).The last classification of beliefs about teaching with technology was made by Zbiek and Hollebrands (2008) based on teachers' concerns. They identified beliefs in three groups; *personal concerns*, *management concerns*, and *technology concerns*. Personal concerns consist of teachers' views about themselves. Management concerns are related to classroom management and student learning. Lastly, technology concerns are about using technology effectively (Tyminski et al., 2013).

Abbitt (2011) suggested promoting PSTs' TPACK may lead to belief change in teaching efficiently with technology. Enabling PSTs to think about using technology differently and effectively is another way of actualizing belief change (Brown, 2015). But factors such as role of the subject and school culture are needed to be considered when investigating PSTs' change in technology practices (Ertmer & Ottenbreit-Leftwich, 2010).

Researches in which PSTs were asked to plan and implement technology-based lessons found that PSTs' views and beliefs shift from using technology to do math faster or practice drill towards enabling relational understanding and conceptual knowledge with technology (Cavin, 2007; Mudzimiri, 2012; Ozgun-Koca et al., 2010). Harrington (2008) found out that PSTs' beliefs changed through a mathematics licensure program in which TPACK development was encouraged with field experience, TPACK-centered assignments and discussions. PSTs' beliefs moved from *doing technology* to *using technology* and from considering technology as *an extension/simplifier* to *an enhancer/differentiation* in the purpose component. In the student component, PSTs' views were identified as *visualizing and abstraction with technology,* and *motivation.*

Purpose and Research Questions

It may be implied that PSTs' beliefs play an important role in predicting their future decisions and classroom practice related to technology. Determining what they think about teaching with technology within the context of technology's role, students, curriculum, and instructional strategies may help teacher educators to revise teacher preparation programs. This study took three semesters. PSTs' beliefs were traced during a long time. Merriam (2009) stated that collecting data for a long time gives researchers the opportunity to analyze data continually and to clarify concepts. This allowed the researchers to see the factors that shaped PSTs' beliefs and to find the patterns in their belief change while PSTs were enhancing their skills and knowledge about mathematics, pedagogy, and technology. This study aims to investigate PSTs' beliefs and changes in their beliefs about TPACK. For this purpose, TPACK components developed by Niess (2005) were used. Researchers attempted to answer the questions below:

(1) What were PSTs' overarching conceptions about the purposes for incorporating technology in teaching mathematics and how did they change during study?

(2) What were PSTs' beliefs about students' understandings, thinking, and learning in mathematics with technology and how did they change during study?

(3) What were PSTs' beliefs about curriculum and curricular materials that integrate technology in learning and teaching mathematics and how did they change during study?

(4) What were PSTs' beliefs about instructional strategies and representations for teaching and learning mathematics with technology and how did they change during study?

(5) What were the factors that affected PSTs' beliefs about TPACK components?

METHOD

This study is an embedded-multiple case study aimed to (a) answer "how" and "why" PSTs' beliefs of TPACK change, and (b) determine the contextual conditions that have an impact on PST' beliefs of TPACK (Yin, 2003). Six PSTs were taken as different cases and TPACK components developed by Niess (2005) were determined as the unit of analyses. PSTs were selected due to their different mathematical and technological background. With this various selection, researchers attempted to gain a common pattern of PSTs' beliefs with the help of semi-structured interviews.

Context

There have been several developments related to teacher education and curriculum since early

2000s in Turkey. Technology was first seen in National Mathematics Curriculum in 2005 and using technology effectively was considered as an essential skill that students are expected to have in 2009. In consistent with these developments, Turkey Ministry of Education developed a project called Movement of Enhancing Opportunities and Improving Technology (FATIH) in 2010 and began to put the project into action in 2012. Within the context of FATIH project, classrooms and schools were equipped with available technological tools such as interactive boards, tablets, internet access and specific portals (Ministry of National Education, 2016). This project has been the greatest training investment about educational technology use to date in Turkey. This may imply that technological opportunities are developing recently and preparing teachers to teach with technology is becoming a crucial issue in order to achieve the objectives of FATIH Project in Turkey.

The first two years are mostly content-based in Teacher Preparation Program (TPP) in which study was conducted. PSTs begin to enroll subject-specific method courses from third year of program. Field experience is two-semester long, in the last year. First semester of field experience includes PSTs' observations about school distinct, administrators, co-operating teachers, students, and technical and physical features e.g.; second semester includes teaching practicum of PSTs. In the TTP in which this study is carried out, PSTs learn *GeoGebra* and *Mathematica*. *PowerPoint* representations were the most common used technological tool. Mathematics class had interactive whiteboards and mathematics software, and virtual manipulatives. In Turkey students enter high-schools and universities with central entrance exams in which there are multiple-choice questions that must be answered at a given time. These exams make students and teachers pay more attention to results instead of solution process. Therefore, most of them didn't learn mathematics or any subject matter with technology to get a rich repertoire of solutions to problems in a short span of time.

Participants

Participants of this study were 6 PSTs who were juniors at a mathematics teacher preparation program in the midst of Turkey at a rural setting. Participants were determined purposefully via maximum variation sampling to represent different cases in terms of technology and mathematics and to get a comprehensive understanding of perspectives of the different cases (Creswell, 2012). This variation in participants may lead to present different findings. A TPACK self-assessment survey and a polygon questionnaire were administered to 33 PSTs. TPACK survey was developed by Kartal, Kartal, and Uluay (2016). The survey was 7 point Likert style and consists of 67 items which aim to identify pre-service teachers' self-assessments about teaching with technology. However, polygon questionnaire (Kartal & Çınar, 2017) included 19 open-ended items related to PSTs' mathematical knowledge of polygons. 6 PSTs were chosen based on their scores from TPACK survey and polygon questionnaire. Their scores were classified into three levels due to a formula used by Fettahlioglu, Ozturk, Dag, Kartal, and Ekici (2012). Table 1 shows the PSTs' level of TPACK and mathematical knowledge of polygons in the study group.

Table 1. PSTs' levels of TPACK-self assessment and mathematical knowledge of polygons

Participant	TPACK	Polygons
PST-1	High	High
PST-2	High	Low
PST-3	Medium	High
PST-4	Medium	Low
PST-5	Low	High
PST-6	Low	Low

Data Collection Tool

PSTs' beliefs about TPACK were examined through face-to-face interviews which are one of the main data collection sources to examine "how" and "why" questions in case study (Yin, 2003). A draft of interview protocol was developed based on the four TPACK components reviewing literature (Cavin, 2007; Harrington, 2008; Mudzimiri, 2012; Niess, 2013). Draft has been sent to two experts who have studied TPACK. After expert review, pilot of the draft has been performed with two PSTs. The PSTs weren't participant and they were asked to read, think about and answer questions aloud (Bowles, 2010). The aim of think aloud strategy was to be sure that items were understood by PSTs in the same way. Final form of the interview protocol has questions related to PSTs' views about TPACK components (Appendix). Interviews were conducted five times (Figure 2) and took approximately 20 minutes. The same interview protocol was used for each interview to identify different patterns of belief change. All of the interviews were recorded with the permission of participants.

Data Collection Process

This study occurred in the PSTs' natural setting during a method course and field experience. PSTs were interviewed five times. At the beginning of the study PSTs were interviewed for the first time. It has been seen that PSTs believed that technology should be used for the purpose of brief and visual representation of mathematical concepts at the end of the interview. Workshops were designed to attempt changing their beliefs from using technology as a representation tool to using as a learning tool and focused on TPACK, how to integrate technology, pedagogy and mathematics. Five workshop sessions took totally ten hours. The sessions aimed to demonstrate using different technological tools (e.g. calculators, applications, websites, dynamic geometry software, and computer algebra systems) in such a way that enable students to explore mathematical ideas with these tools. Models of teaching different topics such as numbers, geometry and algebra were shown. First researcher acted as a teacher and PSTs as students. PSTs have known GeoGebra and they reported that they didn't think to learn and use new software in their teaching practices because of language. GeoGebra serves in Turkish and this feature makes GeoGebra practical and attractive in Turkey. They weren't introduced new software instead they were encouraged to use technology in a constructive and fruitful way.

After workshops PSTs were interviewed for the second time. Method course was designed to promote PSTs to understand approaches, strategies, and issues that are relevant to the teaching and learning of mathematics. They were introduced how to teach numbers, fractions, geometry, algebra, and measurement. Technology was integrated with some applications, smartboard and Web sources into the course but, TPACK was not mentioned especially. Then, they planned and implemented a short technology-based microteaching in the context of method course. They evaluated their microteaching practices and implemented the same profession second time to a different group. Third interview were performed with them at the end of method course. Data collection process is given in Figure 2.

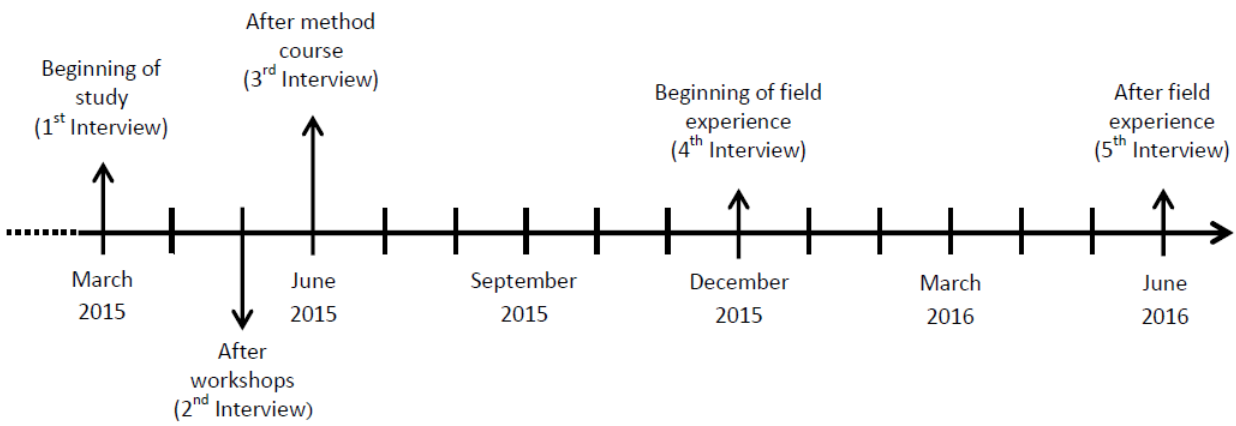

Figure 2. **Time schedule showing when interviews were performed**

PSTs began to make observations in the context of field experience. Sometime later, they were interviewed for the fourth time and then they planned and implemented two technology-based lessons in real classrooms within the context of study. Their implementations were videotaped and six PSTs watched all of the videos; evaluated and discussed the first implementations of themselves and their peers. After evaluation meeting, the first researcher came together with groups individually and guided them to plan the second implementation. The topic they chose to teach wasn't different in the implementations. They re-planned their lessons based on their and peers' evaluations and taught the same topic to a different group. The aim of the implementations was determined as effective technology integration and mathematical explorations made by students. Following re-planning, PSTs implemented their re-planned lessons second time in real classrooms. They were interviewed for the last time after field experience, just before their graduation.

Data Analysis

Content analysis was used in this study. TPACK components of Niess (2005) were determined as the themes of qualitative data. Interviews were transcribed in their entirety and coded based on the four components using a codebook (Table 2) which was developed by researchers reviewing the literature related to TPACK components (Harringhton, 2008; Meagher et al., 2011; Mudzimiri, 2012; Niess, 2013). After coding, similar codes were gathered so as to constitute categories. For example, the codes of *drawing students' attention to mathematics* and *making students enjoy mathematics* created the category of *developing positive attitudes*. Once data for a participant were analyzed, the process was repeated with the data for other participants respectively. After analyzing all the data, similarities and differences in codes were examined to form a pattern in the change of TPACK components. Researchers analyzed the data independently due to codebook and then came together to explain their codes and interpretations. They discussed on the similarities and differences between their coding schemes and argued until 100% consistency was reached (Miles & Huberman, 1994).

Table 2. Codebook used for data analysis

Knowledge component	Descriptive component
Conception about purposes for incorporating technology	Role of the technology How technology supports student to learn important ideas How to use technology
Knowledge of students' thinking and learning with technology	PSTs' views about how students learn mathematics with technology PSTs' views in which they place themselves in the position of the students
Knowledge of curriculum and curricular materials	PSTs' views about appropriate technological tools that can be used in mathematics education
Knowledge of instructional strategies and representations	Knowledge of instructional strategies and representations to teach a particular mathematical content PSTs' views about technology use PSTs' views about whether using technology to support known concepts or to develop new concepts

Reliability

Reliability is the credibility of qualitative studies. Initially, *prolonged engagement in the field* was conducted (Creswell, 2012). First researcher attended the teaching method course during two semesters to make PSTs feel comfortable with her. This was an important component of building trust with PSTs. Triangulation of data source was carried out by gathering data from participants who have different technological background and mathematical knowledge (Plano Clark & Creswell, 2015). Peer review was the last step for trustworthiness. Researchers planned and organized study together. Especially, researchers examined the data independently in data analysis.

FINDINGS

Data from each of the TPACK components was analyzed independently to see the change during method course and field experience for each participant and discover patterns from participants. Original quotes from PSTs were given to provide comprehensive understanding about components.

PSTs' Belief Change in Overarching Conception about the Purposes for Incorporating Technology in Teaching Mathematics

The first component about purpose for integrating technology in teaching mathematics refers to teachers' beliefs of what is important in that subject and how technology supports students to learn that important point, and what teaching with technology means for PSTs (Niess, 2013). These views are often untried by PSTs (Meagher et al., 2011). PSTs' views about overarching conception were analyzed into two subcategories; *the role of technology* and *how technology support students.* PSTs' beliefs about their overarching conceptions of teaching mathematics with technology were given in Table 3.

Table 3. PSTs' beliefs about their overarching conceptions of teaching mathematics with technology

		Technological self-assessment level		
Time		High	Medium	Low
At the beginning of study	Role of technology	Visual representation Provides proof without words	Visual representation	Visual representation
	How technology supports students	-	-	-
After workshops	Role of technology	-	Visual representation Motivation Simplifier Giving more examples	-
	How technology supports students	If students access technology individually	-	-
After method course	Role of technology	Simplifier Giving more examples Calculations Motivation	Visual representation Simplifier Giving more examples Provide accurate diagrams Motivation	Visual representations Enables concrete representations of abstract ideas
	How technology supports students	Students should access technology individually Meaningful learning	-	-
Beginning of the field experience	Role of technology	Visual representation Simplifier Provide accurate diagrams Motivation	Visual representation Simplifier Provide accurate diagrams	Visual representation Simplifier Giving more examples Motivation

	How technology supports students	Meaningful learning	Promoting estimation and generalization	Meaningful learning
After field experience	Role of technology	Visual representation Simplifier Provide accurate diagrams Motivation	Motivation Summarizing	Visual representation Simplifier Giving more examples Motivation
	How technology supports students	Meaningful learning Preventing misconceptions	Promoting generalization Preventing misconceptions	Meaningful learning

It can be seen that PSTs perceived the role of technology as a visualization tool. Only one PST with a high level of mathematics and technological self-assessment remarked that visualization provides students proof without words. None of them didn't state an opinion about how visualization supports student learning. One PST argued that technology cannot be used for all mathematics topics and insisted on visualization especially in order to concrete:

"Technology doesn't work for all topics in mathematics, but it (technology) is really useful for some topics which can be visualized. It has an importance in concretization." (PST-3)

After workshops, only PSTs that have a medium-level self-assessment about teaching mathematics with technology reported their beliefs about the role of technology. PSTs' beliefs about the ability of technology to make things easier constituted the idea of *Simplifier*. In the second interview, PSTs remarked that it is easier to give more examples with technology. PSTs pointed out that the accessibility of technology by all of the students is an important factor in supporting students' learning. At the end of the method course, they insisted on visualization. But they added purposes for integrating technology such as motivation and simplifying. PSTs' beliefs about role of the technology such as making the lesson more enjoyable and drawing students' attention created the emerging theme "*Motivation*". PSTs argued that using technology for these purposes help students learn mathematics meaningfully and have a relational understanding. A PST explained how dynamic geometry software (DGS) simplifies drawing more and accurate diagrams and how this helps saving time and avoids rote learning. Another PST reported that she realized to teach mathematics enjoyably:

"For example, if I attempt to draw a rectangular and parallelogram on the blackboard, I have to show different types of geometric shapes. But dragging gives the opportunity to gain a new view of that geometric shape in DGS. It avoids losing time. Students see accurate shapes and I think this helps them to understand what really that shape is and to avoid memorizing." (PST-3)

"In fact, mathematics can be taught in an enjoyable way with technology. Math is mostly known as boring, but we can do math lessons more enjoyable and direct students' attention to lesson more." (PST-4)

At the beginning of the field experience, all of the PSTs emphasized the same roles of technology; *Visual Representations, Simplifier,* and *Motivation*. But new beliefs about how technology promotes student learning emerged. PSTs that have a low-level technological self-assessment asserted that technology enhances students' estimation and generalization abilities. In addition to these, preventing misconception was considered as another contribute to student learning at the end of the field experience. PSTs specified that technology can provide opportunities for students to develop their estimating and generalizing ability; to prevent misconceptions; to learn in a meaningful and relational way; to overcome the difficulties about some topics in which they have problems of envisioning.

"There are some properties which I can show easily with DGS. For all parallelograms, the opposite

angles are equal. I can show this on GeoGebra for as much shapes as possible. The angle that occurs where diagonals bisect each other may be 90° *or not, you can demonstrate that intersection angle of diagonals is not always* 90°. *We may prevent misconceptions in this way and help students to generalize." (PST-1)*

PSTs' Belief Change in Knowledge of Students' Understandings, Thinking, and Learning in Mathematics with Technology

The second component about students refers to how students can think about, understand and learn mathematics with technology (Niess, 2013). Also PSTs' views in which they substitute for students belong to this component. PSTs' beliefs were examined into two groups; *beliefs about thinking about mathematics with technology* and *beliefs about learning mathematics with technology.* PSTs' beliefs were given based on their levels of technological self-assessment in Table 4.

Table 4. PSTs beliefs about students' understandings, thinking, and learning in mathematics with technology

		Technological self-assessment level		
Time		High	Medium	Low
At the beginning of study	Thinking about mathematics with technology	Developing positive attitudes	-	Developing positive attitudes
	Learning mathematics with technology	Conceptual and meaningful learning Promotes learning topics that are considered as difficult	Conceptual and meaningful learning	-
After workshops	Thinking about mathematics with technology	-	Developing positive attitudes	-
	Learning mathematics with technology	-	Problems with time Conceptual and meaningful learning	-
After method course	Thinking about mathematics with technology	Developing positive attitudes Thinking in detail	-	-
	Learning mathematics with technology	Conceptual and meaningful learning	Conceptual and meaningful learning Discovering mathematical ideas Promotes learning	Conceptual and meaningful learning Preventing memorization
Beginning of the field experience	Thinking about mathematics with technology	Developing positive attitudes	-	-

	Learning mathematics with technology	Discovering mathematical ideas by coping with technology individually Possibility of laziness in the case of overusing	Preventing misconception The importance of grade level	-
	Thinking about mathematics with technology	Developing positive attitudes	-	Developing positive attitudes
After field experience	Learning mathematics with technology	Discovering mathematical ideas by coping with technology individually Meaningful learning	Meaningful learning Understanding the basic properties of a geometric concept	Understanding the basic properties of a geometric concept Conceptual and meaningful learning

The emerging themes were *developing positive attitudes* and *conceptual and meaningful learning* at the beginning of the study. Developing positive attitudes means drawing students' attention to mathematics, overcoming prejudices about math, or making them love mathematics. But they did not tell anything about how technology helps to gain aforementioned outcomes. It was seemed that PSTs took themselves as a reference and addressed that visualization facilitates learning:

"Visual manipulatives or representations help me learn in a meaningful and constructive way, so I think students can learn mathematics in the same way with technology." (PST-6)

When the method course ends, there was a development in PSTs' beliefs. They remarked students' interest of technology in their daily lives and suggested that they will love mathematics, and then want to do mathematics if the interest of technology integrates with mathematics. But, they mentioned a constraint. If students are supposed to learn mathematics with technology in a meaningful and conceptual way, all of the students should access technology easily and have the opportunity to accomplish tasks with technology. This idea led a concern in PSTs that have a low technological self-assessment. They pointed out the time problem when students were unchecked. It was assumed that PSTs realized that technology can be used effectively only when all in the class have and know the technology used. This might be an implication that PSTs learnt from their microteaching practices.

There are two quotes from PSTs below. One of them is related to how technology enables conceptual learning. The other one is an important point that should be considered in order to support students to learn mathematics with technology:

"Students can see more and different examples in a sort span of time and this promotes and makes easier learning." (PST-3)

"It is important that everyone in the class must get the access to technology. If students know how to use technology, they can explore mathematical ideas and don't need to memorize rules."(PST-1)

Another concern that PSTs reflected was that technology may take students' thinking's place. A PST explained the reason of this concern and remarked the guidance of teachers that forbid using calculators. But, observing and implementing lessons with technology in real classrooms seemed to develop PSTs' beliefs about students' understanding with technology. When students would be encouraged to engage activities with technology, this allows them to observe all details in mathematical processes visually; to see the actual figures and measurements. Thus misconceptions can be prevented and students may realize what a mathematical concept consists of and what is needed to construct the concept. A quote that underpins briefly these findings is as follows:

"Students can see the equality of angles and sides easily in a regular polygon given in DGS." (PST-5)

One PST who had a medium level technological and mathematical background (PST-4) compared her two implementations with and without technology. She told that she could only give one or two perspectives of a parallelogram on the blackboard. She stated "*Maybe they (students) thought that properties were valid for only those perspectives I drew on blackboard."* She emphasized that students might conceptualize a prototype parallelogram that is a parallelogram with a pair of horizontal and vertical sides leaning to the right. However, she argued that GeoGebra gave her the opportunity to show that a rectangular is also a parallelogram. In her opinion, she told students that opposite sides and opposite angles is equal in parallelogram and they accepted. They didn't have a chance to see the equality in sides and angles actually. Another PST reflected that if a triangle is 'upside down' in which the horizontal base of the triangle is on top and the opposing vertex below, she was confused about properties of triangle. She mentioned that students can see the basic properties of a geometric concept regardless of how it looks with DGS.

PSTs' Belief Change in Curriculum and Curricular Materials That Integrate Technology in Learning and Teaching Mathematics

Teachers consider how to teach topics in curriculum with technology and evaluate technological tools that can be used in mathematics education. Grossman (1990) reported that PSTs' pupilage observations underlie their decisions about curricular materials in their teaching professions. They don't regard about their teachers' choices and tend to make the same. PSTs' beliefs about this component were examined into two subcategories; *curriculum* and *GeoGebra*. Participants stated that they don't need to learn new software because they have already known GeoGebra that is easy to use for them. They weren't introduced any software. GeoGebra constituted the most of experiences that PSTs have about teaching and learning mathematics with technology. They mostly mentioned GeoGebra during interviews. Thus, GeoGebra was determined as a subcategory. PSTs' beliefs about curriculum and curricular materials that integrate technology in learning and teaching mathematics were given in Table 5.

Table 5. PSTs' beliefs about curriculum and curricular materials that integrate technology in learning and teaching mathematics

		Technological self-assessment level		
Time		High	Medium	Low
At the beginning of study	Curriculum	Geometry Searching about topics in the internet	Geometry Topics that are considered as difficult	Geometry Searching about topics in the internet Solids Tending towards manipulatives
	GeoGebra	Dragging Appropriate for solids	-	-
After workshops	Curriculum	-	Topics that are available for visualization Tending towards manipulatives	-
	GeoGebra	-	-	-
After method course	Curriculum	Different topics from geometry can be taught with technology (e.g. algebra) Solids Topics in which PSTs have difficulty	Tending towards manipulatives Different topics from geometry can be taught with technology	Using technology enhances teaching curriculum Different topics from geometry can be taught with technology (e.g. algebra)
	GeoGebra	Provides accurate drawings in a short time	Provides lots of examples in which particular properties are valid	Construction
Beginning of the field experience	Curriculum	Tending towards manipulatives	Geometry CAS enables making calculations in an easy and short way	Geometry Tending towards manipulatives
	GeoGebra	-	Provides instant feedback	-
After field experience	Curriculum	Tending towards manipulatives Topics that are difficult to visualized	Topics in which PSTs have experiences about teaching with technology	Can't teach all of the curriculum with technology
	GeoGebra	Appropriate for solids Facilitates rotating solids and front-right-top (FRT) view Provides accurate drawings in a short time	Dragging Provides accurate drawings in a short time	-

At the beginning of the study, all of the PSTs thought that technology can be used in geometry or topics that are appropriate to visualize. They explained the reason of their preference as having more experiences with technology in geometry. They commonly reported that GeoGebra enables them to show that the basic properties of a geometric shape don't change even though the appearance changes. One PST stated as follows:

"I can use technology mostly in geometry topic, this is because I know GeoGebra and feel confident about using it." (PST-3)

PSTs' beliefs seemed to be affected by workshops. They were demonstrated the use of technology in different topics such as algebra. All of them expressed that they realized teaching different topics from geometry with technology. But, they still insisted on considering visualization as a criterion to decide where they use technology. However, a comparison was seen between technology and manipulatives. PSTs specified that manipulatives outweigh technology and didn't give any explanation about why. PSTs also referred that they can make actual drawings shortly and show a lot of examples for which a set of properties work with GeoGebra. The following original quotes underpin these findings:

"Even though the side lengths and angles vary, it is always a parallelogram. And you can show this in a short time." (PST-5)

"At that time (beginning of the study) I thought I can teach a little with technology. But now, I realize there are more than I thought I can." (PST-1)

Manipulatives versus computer applications or software is the most common seen belief after field experience. Some of PSTs reported that they will use manipulatives because they feel more confident with them than technology. They also stated that students didn't pay attention to GeoGebra as much as they expect in their technology-based implementations. This may be because only PSTs had the opportunity to use GeoGebra on the interactive whiteboard.

"It may be easier to use manipulatives for me because of familiarity with them. They are in evidence, students can touch and see. Even though today's students are too interested with technology, I didn't observe any excitement when I introduced GeoGebra to students. I think this happened because they didn't know anything about GeoGebra. But, I remembered my pupilage, when our teacher used manipulatives we really got excited and payed attention."(PST-2)

Another insistent opinion about teaching geometry with technology appeared again at the end of the study. However, PSTs' observations emerged as an important factor affecting their beliefs especially about GeoGebra. When the last interview was conducted, PSTs had implemented two mathematics lessons with technology. Even though these implementations improved their views about GeoGebra, they insisted on using GeoGebra in geometrical concepts.

"I think GeoGebra can be used only for geometry topics. It may be mathematics software but we use it for geometric concepts. Look at the tools above in GeoGebra. They are related to angles, polygons etc. So I think it is fundamentally related to geometry and appropriate for geometry."(PST-3)

They also addressed the opportunity to show students how to construct mathematical concepts in detail. One PST clarified this statement as the following:

"For example, let us construct a square in GeoGebra. We can ask students what we need to draw a square. They might answer as four sides. We can test whether only four sides are enough for a square with GeoGebra. I think students can see what is needed for mathematical concepts in detail."(PST-4)

PSTs' Belief Change in Instructional Strategies and Representations for Teaching and Learning Mathematics with Technologies

PSTs' had minimum beliefs about instructional strategies related to teaching and learning mathematics with technology. Because their experiences that integrate technology into teaching mathematics were limited. A contradiction was observed between PSTs' beliefs about how technology should be used and beliefs about drawbacks of technology such as class control and time problem.

At the beginning of the study, PSTs thought that technology can be used to support known concepts (Table 6). They emphasized that students should master mathematical concepts by hand before using technology. This may imply that PSTs don't feel comfortable with technology and don't trust on technologies too much. PSTs in the high level of technological self-assessment added using technology to develop new concepts within the context of student-centered instruction. One PST's statement that addressed supporting concepts is as follows:

"I think we should use traditional methods firstly in order to encourage students to think and learn about mathematics better. After teacher's lecturing, technology can be used." (PST-6)

It can be seen that PSTs' beliefs shifted towards constructivist teaching with workshops and microteaching. They told about learner-centered instruction that aims to develop new concepts. They suggested that teachers should help their students to reason and deduce with technology. Workshops that are designed as technology-based and student-centered mathematics lessons were considered as effective in changing PSTs' beliefs. The following PST's quote mentions the relationship between the instructional strategies and teachers' intention to use technology;

"A teacher may use technology only by oneself and be the only one who controls the technology during teaching and learning mathematics. But, they should guide students to make calculations or assumptions, find patterns, and explore mathematical ideas. Teachers' choices about instructional strategies affect technology use and role of the teachers and students."(PST-4)

Table 6. PSTs' beliefs about instructional strategies and representations for teaching and learning mathematics with technologies

	Technological self-assessment level		
Time	High	Medium	Low
At the beginning of study	Supporting known concepts Developing new concepts Problems with time Learner-centered instruction	Supporting known concepts	Supporting known concepts
After workshops	Developing new concepts Learner-centered instruction	-	-
After method course	Learner-centered instruction Discovery learning Better than lecturing	Teacher's role: guide Learner-centered instruction Students should be active with technology Students should reason and deduce with technology	Teacher's role: guide Class control
Beginning of the field experience	Problems with time Promotes student-teacher interaction	Developing new concepts Teacher's role: guide Students should be active with technology Class control	Teacher's role: guide Students should be active with technology
After field experience	Class control Lacking knowledge about GeoGebra Technical problems Inquiry-based instruction Direct instruction if only teacher is active	Students can discover mathematics if only they engage with technology Direct instruction if only teacher is active Class control	Direct instruction if only teacher is active Teacher's role: guide Students should be active with technology Class control

Whenever they met real learning environments in schools, they started to fear about losing control during technology use. They stated two main reasons of this fear: the possibility of technical problems and not having enough knowledge about technology. According to PSTs' statements, lacking knowledge of GeoGebra made them anxious and they failed to control class. One PST specified that she would not tend to use technology when she started her profession and added that she will hardly decide to integrate technology after feeling as an authoritative teacher. The following quote emphasized why it was difficult for PSTs to control class while engaging with GeoGebra:

"It is too difficult to both teach with technology and to control class. I don't think I am not proficient enough to deal with GeoGebra. I focused on how to use GeoGebra and so I couldn't pay attention to mathematics discoveries. Students talked between each other."(PST-2)

Although they had some wonders, they mentioned inquiry-based technology usage to develop new mathematical concepts. They suggested that teachers should pose questions that require inquiry especially in learning environments in which only teachers have access to technology. PSTs' views show that using technology doesn't always mean enabling students to do mathematics. "Why?" and "How?" questions should be absolutely used to promote student reflection with technology. One PST explained what kind of a strategy should be used to promote students' learning as follows:

"Think a teacher who is attempting to integrate technology by using it only oneself. Technology will not contribute to teachers unless students are included in thinking with technology or using technology to think. Students must be able to make reasoning and be given feedback with technology." (PST-1)

CONCLUSION AND DISCUSSION

PSTs' belief change was examined within the context of TPACK components developed by Niess (2005). PSTs were selected based on their different technological and mathematical background, and were interviewed five times (at the beginning, after workshops, after method course, before and after field experience) to trace how and why their beliefs changed. PSTs had simple beliefs related to TPACK components at the beginning of the study and their beliefs changed along with method course and field experience. It was found that the most important factor which has the most effect on PSTs' beliefs is their experiences about learning and teaching technology in a similar way with other researches (Agyei & Voogt, 2012; Cavin, 2007; Drier, 2001; Mudzimiri, 2012; Niess, 2013).

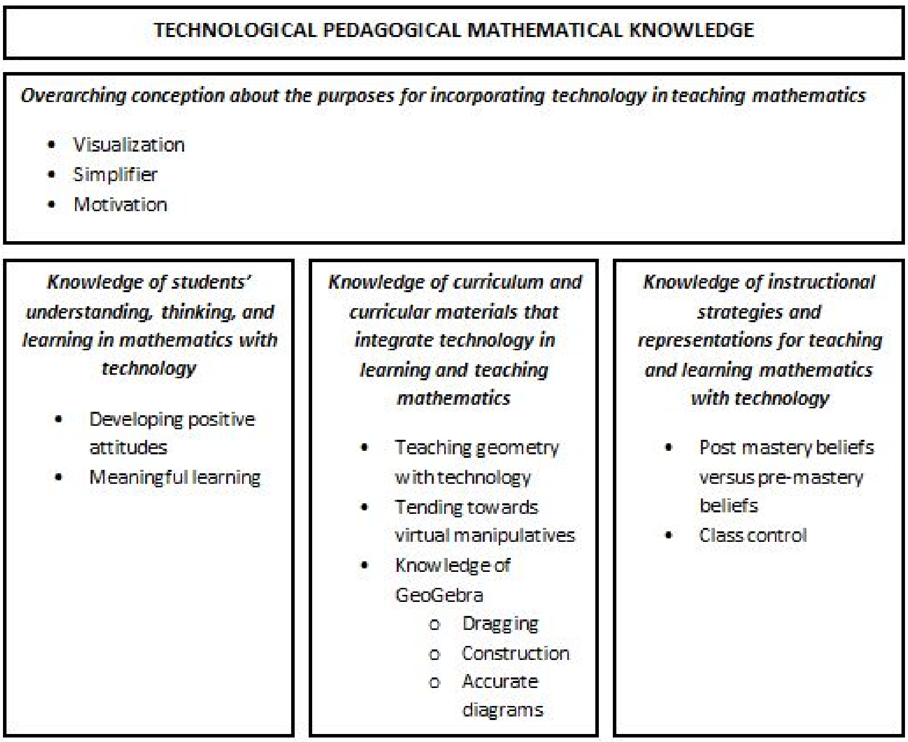

Figure 3. Technological Pedagogical Mathematical Knowledge model of participants

A model for technological pedagogical mathematical knowledge of participants was suggested in Figure 3. Model was developed considering PSTs' continual and common beliefs based on the teacher knowledge model of Grossman (1990). According to technological pedagogical mathematical knowledge model of participants, PSTs consider technology as a visualization, simplifier, and motivation tool. They thought that teaching students mathematics with technology support them to develop positive attitudes towards mathematics and to learn mathematics in a meaningful way. They are familiar with geometrical concepts in teaching with technology so they were of the opinion that only geometry topics can be taught with technology. While their experiences of teaching with GeoGebra increased, they enhanced their knowledge and skills about GeoGebra. Nevertheless, they didn't feel proficient and stated using virtual manipulatives instead of technology. Pre-mastery beliefs seen at the beginning of the study moved towards post mastery beliefs. But, teaching practicums in classrooms caused concerns about classroom management.

PSTs' views were examined due to their mathematical and technological background. Different patterns were only found in the analysis made due to technological self-assessment levels of PSTS. For example, PSTs that have a high level technological self-assessment stated how visualization supports student learning previously from other participants. However, PSTs that have a low level technological self-assessment firstly mentioned class control. Considering how and why PSTs' beliefs change and what the emerging ideas that affect their beliefs are, this section was divided into two sub-headings.

The Pattern and the Reason of Belief Change of PSTs

According to PSTs, teaching mathematics with technology meant visualization of mathematical concepts at the beginning of the study. This view was seen in the similar studies (Cavin, 2007; Harrington, 2008; Mudzimiri, 2012; NCTM, 2000; Tall, 1998). After workshops and method course, they indicated that teaching with technology might provide giving more examples, drawing accurate diagrams and making calculations easier, and motivating students to engage in the lesson. Bakker and Frederickson (2005) and Harrington (2008) found similar patterns about teaching with technology. Field experience didn't lead to a change in their beliefs about the role of the technology, but changed the beliefs about how technology supports students' learning. They stated that technology would promote students' estimation and generalization abilities and prevents misconception if they were able to access easily to technological tools. These findings are underpinned by Agyei and Voogt (2012), O'Reilly (2006), and Tall (1998).

PSTs suggested integrating students' interest of technology with mathematics. This will make students to engage in the lesson and want to learn more mathematics. As they enjoy mathematics more, conceptual and meaningful learning may be reached. In the similar studies, researches (Bakker & Frederickson, 2005; Geiger et al., 2012; Harrington, 2008) mentioned about same affordances of technology in supporting students. PSTs detailed conceptual and meaningful learning after workshops and method course. Discovering mathematical ideas and avoiding memorization were new ideas related to students' learning with technology. PSTs' views are consistent with a study whose participant is a teacher (Guerrero, 2010). PSTs in the medium-level of technological self-assessment identified a drawback about time while students were left by themselves with technology. Observing in schools didn't change PSTs' beliefs so much. One PST expressed that her co-operating teacher overused technology as a representation tool of textbook and identified her wonder about leading laziness in students. PSTs taught polygons with GeoGebra in their field experiences. At the end of the field experience, the emerging theme was students' mathematical discoveries with technology.

PSTs' most common belief about curriculum was that only geometry can be taught with technology. Their learning experiences with technology included mostly GeoGebra activities. They learnt geometrical concepts and provided visual representation of geometrical concepts with GeoGebra. This may be why they thought that geometry is the most appropriate topic for teaching with technology. Workshops led a little change and PSTs realized that different subject matter topics such as algebra can be taught with technology. They didn't teach algebra with technology, so their resistant beliefs about teaching geometry with technology emerged again at the end of the field experience. PSTs' beliefs about GeoGebra developed in all technological levels as long as they implemented lessons using GeoGebra. PSTs' lacking knowledge and skills about teaching different topics from geometry with technology have constraint their beliefs. Similarly, researchers (Chen, 2010; Hew & Brush, 2007; Inan & Lowther, 2010) argued that knowledge and skills are the important factors affecting technology integration.

PSTs had a limited repertoire and naïve beliefs about instructional strategies to teach with technology. All of them emphasized that technology should be used to support concepts after those concepts were mastered by hand. PSTs' beliefs were consistent with yes-but beliefs of Meagher et al. (2011) and post-mastery beliefs of Hanzsek-Brill (1997). Constructivist-based workshops created awareness in PSTs so that they could think that students may discover mathematical ideas with technology. PSTs' beliefs changed from yes-but and post-mastery beliefs to yes-and and exploratory beliefs. When they went to field experience, the issue of class control seemed to shape PSTs' beliefs. Zbiek and Hollebrands (2008) labeled these beliefs as management concerns. PSTs' management concerns affected most of the beliefs even though PSTs made a mention about constructivist teaching with technology. The underlying reasons of having problems with class control were not to have enough knowledge about GeoGebra and technical problems that they may face (Harrington, 2008).

Emerging Ideas Affecting PSTs' Beliefs

Three descriptors were identified as the factors that played an important role in shaping PSTs' beliefs. These descriptors are *visualization, meaningful learning,* and *class control*. Visualization was the most affective view in most of the components especially at the beginning. PSTs' thoughts about using technology to visualize and support mathematical concepts are the evidence in the first (conception) and fourth (strategy) components. Whenever they talked about students' meaningful and conceptual learning, they referred to visualization. The idea that visualization leads to conceptual learning exists in the similar studies (Cavin, 2007; Harrington, 2008; Tall, 1998). According to PSTs, visualizing will help students to learn mathematics meaningfully. So the most appropriate topic in mathematics curriculum for technology use is geometry and likewise geometry software is the most appropriate tools. They explored mathematical concepts which are mostly related to geometry with GeoGebra. It may be implied that experiences with GeoGebra affected their beliefs.

PSTs enrolled in a teaching method course and workshops independently from the method course. Also, they planned and implemented two technology-based mini lessons within the context of microteaching. Among all of these, workshops seemed to be most effective in PSTs' beliefs. They realized that teachers can teach mathematics in a constructive way with technology. Their beliefs moved from supporting mathematical concepts with visualization (post-mastery and yes-but) to developing mathematical concepts by obtaining a lot of examples and getting students' attention (exploratory and yes-and). PSTs pointed out students' interest in technology in their daily lives consistent with Prensky (2001)'s notion of digital natives and suggested that incorporating this interest with strategies that aim to promote students' discoveries with technology will lead to meaningful learning (Geiger et al., 2012; NCTM, 2000), to make students interested in mathematics (Bakker & Frederickson, 2005), and to keep away from memorizing (Guerrero, 2010). Workshops showed their effect on curriculum component, PSTs reflected that technology can be used in different topics. The reason of this change may be models of teaching algebra with technology that were demonstrated in workshops. Hew and Brush (2007) argued that encouraging PSTs to teach with technology would lead to change in their beliefs. This explains the change in PSTS' beliefs about TPACK with the help of workshops.

PSTs experienced teaching mathematics with technology in real classrooms for the first time in their field experience. It was found that teaching practicums with technology made PSTs anxious about class control. We can make an inference that class control had an important effect on PSTs' beliefs about TPACK components. They realized the difficulty of teaching with GeoGebra, because PSTs had the only access to technology. They had to both use GeoGebra and help students in mathematical explorations. Students were rarely given the opportunity to use GeoGebra. So, they weren't interested as well as that PSTs expect. With these factors, PSTs seemed to tend using manipulatives instead of GeoGebra. They insisted on issue of class control many times.

IMPLICATIONS AND LIMITATIONS

It was seen that PSTs' experiences shaped their beliefs. Their tendency about using manipulatives and GeoGebra is an explicit result of this implication. Also, the lacking of learning mathematics with technology in the pupilage and teaching with technology in classrooms made PSTs' beliefs robust. But, their beliefs changed a little with workshops and technology-based lesson implementations. There is a limited number of software serves in Turkish and this limited Turkish PSTs to feel comfortable about teaching with technology. TPPs which educate PSTs in Turkish should make a point of preparing PSTs to be able to use different software regardless language. Introducing different software and applications before teaching practicums may be a way of expanding PSTs' levels of confidence and experience with technology. The content of method courses should be revised and arranged in order to demonstrate PSTs how technology, pedagogy and mathematics relate to each other.

It was found that PSTs' limited repertoire of instructional strategies made them feel anxious and fear about losing control in their classrooms. Teacher preparation programs should provide opportunities for PSTs to take mathematics courses with technology; to teach more mathematics with technology and to work with teachers who use technology in an effective way in their field experiences. None of the participants didn't work with a co-operating teacher using technology. This may be the reason of why belief change wasn't seen when PSTs first began to field experience. They didn't see a model of teaching with technology. Thus, PSTs may be paired with a co-operating teacher who uses technology actively and effectively and their beliefs may be examined to determine what kind of patterns of belief change occur in further researches. Also, researchers may work with experienced teachers to see to what extent experience affect teachers' beliefs about teaching with technology.

PSTs were asked to teach polygons with technology in this study. Their belief changes about teaching different topics with technology didn't find the opportunity to go into action in PSTs' behaviors. In another study, PSTs may be asked to teach a topic different from geometry and their belief change may be examined. This study is limited with six pre-service teachers. It may be worth exploring how PSTs' beliefs will change if the number of participants increases, and participants are selected based on different criterions such as teaching self-efficacy and self-efficacy of technology integration. Further, a longitudinal study in which it is continued to trace participants after their teacher preparation programs during teaching professions may help to understand beliefs and changes of TPACK in a deeper way.

In brief, PSTs may have strong beliefs about teaching mathematics in traditional ways. This is because they have lack of knowledge and experience in learning and teaching mathematics with technology. This study is an evidence of belief change through workshops and technology-based lesson implementations. But it is still unknown whether their beliefs align with their classroom practice and whether change in beliefs also lead a change in their practices.

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APPENDIX

An overarching conception about the purposes for incorporating technology in teaching mathematics

1. What do you think mathematics is?

2. What is the most important point in polygons that students should learn with technology?

3. What is the role of technology in mathematics education?

4. How does technology affect mathematics and vice versa?

5. What are the difficulties in teaching mathematics with technology?

6. How was teaching polygons with Geogebra?

7. What was the most important point in your implementation and how did technology support your students to learn this important point?

Knowledge of students' understandings, thinking, and learning in mathematics with technology

1. How do students learn mathematics?

2. What do you think about students' attitudes and prejudices related to mathematics?

3. How does technology affect students' learning and thinking styles of mathematics?

4. How did GeoGebra support students' learning and thinking styles of polygons?

5. What are your expectations from your future students?

Knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics

1. What do you know about national mathematics curriculum?

2. How will you decide whether teaching a topic with technology?

3. What do you think about technological tools that can be used in mathematics education?

4. What do you think about virtual manipulatives that can be used in mathematics education?

5. How does technology affect teaching curriculum?

Knowledge of instructional strategies and representations for teaching and learning mathematics with technology

1. How should mathematics be taught?

2. How do teachers teach mathematics?

3. What do you think the most common used mathematics teaching strategy is?

4. How does technology affect teaching mathematics and instructional strategies employed in mathematics education?

5. How does technology affect classroom management?

6. What do you think students can discover mathematical ideas with technology? How?