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Pre-Service Teachers' TPACK Development and Conceptions through a TPACK-Based Course

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Abstract: This study examines pre-service teachers' Technological Pedagogical Content Knowledge (TPACK) development and analyses their conceptions of learning and teaching with technology. With this aim in mind, researchers designed and implemented a computer-based mathematics course based on a TPACK framework. As a research methodology, a parallel mixed method approach was used. The data were collected from 71 pre-service teachers taking the course. The TPACK survey, a semi-structured interview, and evaluation scores of pre-service teachers' microteaching performance, which also included analysis of lesson plans, were used as data collection instruments. The findings indicated that the implemented instructional processes affected pre-service teachers' TPACK development positively. There were significant differences before and after the course implementation concerning Technology Knowledge, Technological Content Knowledge, Technological Pedagogical Knowledge, and TPACK in general. Qualitative findings support and overlap the statistical inferences. There should be more courses which require pre-service teachers to develop computer-based instructional materials and use their materials with microteaching sessions. Instructors of faculties of education should use technology in their instructional environments not only for presentation purposes.

Introduction

Every individual should have the ability of 'learning to learn' (Collins & Halverson, 2009) In modern education, providing high quality and continuous education is a must to educate individuals who in the future will be capable of accessing, searching, and utilizing information (Xu & Chen, 2016). This situation requires information technologies to be integrated into instructional environments so that students will be able to manage and construct their own learning process (Öksüz, Ak, & Uca, 2009). Therefore, educators should not focus only on teaching about technology, rather they must see technology as a tool for enhancing the instructional processes of subjects such as science education, mathematics education, etc. (Baydaş, Göktaş, & Tatar, 2013; Ottenbreit-Leftwich, Glazewski, Newby, & Ertmer, 2010).

Teachers undertake the leading role in the successful integration of technology into learning environments. However, pre-service teachers (PSTs) and also inexperienced in-service teachers (ISTs), who are in the first years of their teaching profession, use information technologies in their classrooms in a very narrow manner and have limited knowledge about technology integration and utilization (Dawson, 2008; Ertmer, 2005; Ottenbreit-Leftwich et al., 2010; Vanderlinde, van Braak, & Tondeur, 2010). Therefore, it is a common recommendation that teachers should be trained especially during their pre-service education about information technologies, technology integration, and teaching and learning with technology (Martinovic & Zhang, 2012; Tondeur, Sang, Voogt, Fisser, & Ottenbreit-Leftwich, 2012). When expressed in general terms it is called 21st century skills for teachers. International Society for Technology in Education (ISTE) publishes standards for teacher competencies. ISTE Standards for teachers are:

1. Facilitate and inspire student learning and creativity,
2. Design and develop digital age learning experiences and assessments,
3. Model digital age work and learning,
4. Promote and model digital citizenship and responsibility,
5. Engage in professional growth and leadership.

The first standard requires teachers to "use their knowledge of subject matter, teaching and learning, and technology to facilitate experiences that advance student learning, ... " (ISTE, 2017, p. 1) In his article Ndongfack (2015) expresses that "one approach through which teachers can acquire skills to effectively adopt technology in the classroom is by working through different stages of professional development to blend technology, content and pedagogy" (p. 1699) which is widely known as TPACK. Ndongfack (2015) explain these stages as recognizing, accepting, adapting, exploring and advancing. These stages are the required stages for teacher competencies in order to master TPACK.

The purpose of this study was to investigate pre-service teachers' TPACK development through a course which was designed and implemented based on a TPACK framework and aimed to provide theoretical and practice knowledge about using technologies for instructional purposes. This study is expected to have significant contributions by providing:

- an understanding about how a TPACK-based course affects pre-service teachers' TPACK development not only with quantitative self-reported data but also supported with qualitative data from interviews and microteaching evaluations and lesson plan analysis and
- information about how a TPACK-based course could be designed and implemented for pre-service teachers so that they can experience an effective technology integration process, and detailed information about the design and implementation of the course is provided.

Technological Pedagogical Content Knowledge (TPACK)

For the last decade, researchers have proposed model suggestions about integrating technological knowledge with pedagogical and content knowledge (Gao et al., 2009; Goktas, Yildirim, & Yildirim, 2009; Keating & Evans, 2001; Mishra & Koehler, 2006; Mishra, Koehler, & Kereluik, 2009; Niess, 2005; Zhao, 2003). The most known and cited (Graham, 2011; Hofer & Harris, 2012) one among others is Mishra and Koehler's (2006) framework for Technological Pedagogical Content Knowledge (TPACK). We also implemented Mishra and Koehler's framework. The framework is an extended version of the original framework (Shulman, 1986), which focuses on Pedagogical Content Knowledge (PCK). There are three primary forms of knowledge: Content (C), Pedagogy (P), and Technology (T) (Harris, Mishra, & Koehler, 2009). Furthermore, the intersections of the three forms of knowledge are Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and the intersection of all three circles is Technological Pedagogical Content Knowledge (TPACK).

There have been several research studies that have focused on determining PSTs' and in-service teachers' TPACK development at different levels for various instructional programs (Balgalmis, Cakiroglu, & Shafer, 2014; Graham et al., 2009; Ozgun-Koca, Meagher, & Edwards, 2009; Powers & Blubaugh, 2005). When teachers' TPACK development increases, their potential to integrate information and communication technologies (ICT) into their instructional process also increases (Archambault & Crippen, 2009; Koehler & Mishra, 2005; 2008; Niess, 2005). However, there has still been no clear answer to the question of how PSTs gain knowledge about technology integration within a specific instructional content area (e.g., mathematics education). A content analysis, based on 74 studies, states that more research focusing on TCK was needed about TPACK (Chai, Koh, and Tsai, 2013). Additionally, K-12 teachers will be utilizing new forms of technology much more in the future. Therefore, pre-service teacher education programs should develop PSTs' TPACK by focusing especially on TCK and by offering courses which include TPACK-based activities.

Mathematics Education and Technology

Mathematics education is one of the fields that stresses the importance of technology integration into instructional processes (Akkaya, 2016) and is one of the most researched fields in this context (Lee & Hollebrands, 2008; Öksüz et al., 2009; Powers & Blubaugh, 2005). The use of computer technologies especially for facilitating cognitive skills for mathematics education is known as computer-based mathematics education (CBME) (Halcon, 2008). The National Council of Teachers of Mathematics states that computers (in general technology) can be used in mathematics education for teaching concepts, developing abstract thinking based on concrete experiences, and problem solving (NTCM, 2000).

GeoGebra, a type of dynamic mathematics software, was used in this research. GeoGebra includes modules such as geometry, algebra, and calculus, and each can be used for classroom instruction interactively (Mainali & Key, 2012). GeoGebra is free (due to its open-source nature) and because of this it has an extensive user community. Dynamic mathematics software has been used by many researchers and teachers in mathematics classrooms. This kind of software provides multiple presentation formats (numerical, algebraic, and graphical and visual) that facilitate students' understanding about content and develop problem-solving and modelling skills by supporting different thinking skills (MEB, 2013). ISTs have not had enough knowledge about teaching mathematics with technology, but when they have been introduced to this kind of technology during their pre-service education program their perceptions, attitudes, and skills towards integrating technology into learning environments has changed positively (Haciomeroglu, Bu, Schoen, & Hohenwarter, 2009; Meagher, Özgün-Koca & Edwards, 2011). Tatar, Kağızmanlı, and Akkaya (2013) analysed 126 research papers about technology-based mathematics education. They found that there were few research studies which focused on the use of software for teaching and learning mathematics and recommended that researchers conduct more research studies on this subject.

Mathematics Education and TPACK

Developing both PSTs' and ISTs' TPACK levels will lead to better technology integration into classroom instruction. Therefore, courses about technology integration in a specific content area (e.g., mathematics education) are becoming an important point for pre-service teacher education programs. There are very few research studies that directly focus on mathematics education and TPACK. The most recent study conducted by Balgalmis et al. (2014) focused on three PSTs' development of TPACK by examining their experiences. The three PSTs designed and implemented three technology based lessons, primarily with GeoGebra. The researchers reported that although PSTs showed progress in general they were not successful when integrating technology into classroom instruction was required. The researchers concluded that PSTs' experience with integration processes should be developed.

Haciomeroglu, et al. (2009) designed a research study in which PSTs used GeoGebra within the framework of TPACK. The PSTs developed course materials using GeoGebra and performed microteaching. PSTs developed materials collaboratively and presented their materials in their microteaching sessions. They reported that developing instructional materials and microteaching contributed to PSTs' development of TPACK. However, their study didn't focus sub-domains of TPACK development especially TCK. The researchers concluded that to develop TPACK, teacher training programs should offer courses that cover content area specific software (such as GeoGebra) and require PSTs to develop instructional materials and use them for classroom instruction.

Another study conducted by Meagher et al. (2011) investigated PSTs' use of digital technologies for teaching and learning processes within the framework of TPACK. They reported that using advanced digital technologies affected PSTs' perceptions and when use of digital technologies was combined with inquiry-based teaching strategies, PSTs' development of TPACK increased.

A literature review study conducted by Tatar et al. (2013) analysed 126 articles in the field of technology-based mathematics education. Their content analysis showed that there were few research studies that focused on content-area software specific to mathematics education. They concluded that there was a need for research studies that focused on use of content area-specific software and integration of such tools into classroom instruction. Young (2016) based on his meta-analysis concluded that instructional practices are needed for improved mathematics teaching with technology. Patahuddin, Lowrie and Dalgarno (2016) states that activities which require teachers utilizing technology-based materials in their teaching practices can be a powerful tool in developing pre-service and in-service teacher's TPACK. To sum up, research studies show that there has been a need for studies that focus on

a) use of content area-specific software or technology-based instructional materials,
b) PSTs' use of technology (which covers developing instructional materials and using them for classroom instruction) and
c) investigating pre-service and in-service teachers' development of TPACK through courses which are designed based on a TPACK framework.

Purpose and Significance of This Study

This study aimed to analyse PSTs' development of TPACK through a course implementation that was designed and implemented based on a TPACK framework. The main research problem was whether a CBME course has an effect on PSTs' development of TPACK levels and sub-knowledge domains, especially in T, TPK, and TCK. The following sub-research questions were asked:

(1) What are PSTs' TPACK and sub-knowledge domain levels before and after the TPACK-based course implementation?
(2) Is there a significant difference between PSTs' TPACK and sub-knowledge domain levels before and after the TPACK-based course implementation?

(3) Is there a relationship between PSTs' microteaching scores and TPACK points before and after the TPACK-based course implementation?
(4) What are PSTs' conceptions of learning and teaching with technology before and after the TPACK-based course implementation?

Most of the studies in the literature have shown PSTs' TPACK levels descriptively or have presented information about their development of TPACK based only on survey findings. However, there have been very few research studies that have analysed PSTs' development of TPACK that have included both quantitative and qualitative data.

The value of including qualitative data is that the responses participants provide show their knowledge and opinions more explicitly than answers given only to survey items. Since this study used data from both the TPACK survey and PSTs' knowledge and opinions to reveal their development of TPACK, this study was expected to contribute to the literature by providing information and perspectives about

a) quantitative and qualitative analysis for TPACK,
b) designing and implementing a TPACK-based course and
c) PSTs' development of TPACK in mathematics education

The main limitation of this study was that the data was collected before and after implementation of only one course during only one semester (10 weeks). A longitudinal study which focuses on PSTs' development of TPACK over a longer period might provide more detailed information. The main strength of this study is that the current study did not rely only on self-reported data. The research data also included microteaching scores given by course instructors to evaluate their teaching practice and interviews with all of the participants in order to understand PSTs' knowledge more deeply.

Methods

As a research methodology, a parallel mixed method approach was used. A mixed methods methodology has been defined as combining quantitative and qualitative techniques in various sequences and emphases (Creswell, 2008; Johnson & Onwuegbuzie, 2004). A mixed method approach helps researchers to increase the quality of their results based on the idea of non-overlapping strengths and weaknesses. In this study a convergent parallel design (Creswell & Plano Clark, 2011) was used. In detail, quantitative and qualitative data were collected in parallel and data were embedded, compared, and contrasted in the findings.

Participants

The participants of the study were fourth year undergraduate PSTs taking a computer-based mathematics education course at a large-scale public university in Turkey. After completing the fourth year PSTs graduates and enter a national examination to be in-service teacher. Seventy-one PSTs (53 female and 18 male) participated in the study.

Design of the Course and Process of Implementation

PSTs' TPACK levels need to be developed for technology-enhanced classroom instruction. Therefore, courses aiming to teach about the relationship of content areas and technology integration have gained importance especially for teacher training institutions. One of the developed courses was the computer-based mathematics (CBM) course, which was offered as a compulsory subject between 1998 and 2005 and an elective course after 2005 in mathematics education programs in Turkey. Most mathematics education programs have offered the course at the senior level. The aim of the course has been to provide information about how to integrate mathematics education with technology, teaching and learning with technology, and the use of dynamic software related to mathematics education (Yenilmez, 2009). When the TPACK framework is considered, the course could be attributed as aiming to integrate Content Knowledge (CK) and Technology Knowledge (TK) to become Technological Content Knowledge (TCK). Besides, if the implementation of the course has been designed based on an instructional design model, the course could support PSTs' development of Technological Pedagogical Knowledge (TPK) and Pedagogical Content Knowledge (PCK).

The course implementation took 10 weeks, not including examinations. The subject topics taught included instructional technology, using technology in educational settings, teaching and learning with technology, mathematics education and technology, and software (GeoGebra) specific to mathematics education. The implemented course focused on GeoGebra, as the Turkish Ministry of National Education (MoNE) has suggested and encouraged teachers to use GeoGebra in their classrooms. For example, the secondary education mathematics instructional program has as a learning gain: "5.2.2.3. Understands basic properties of rectangle, equilateral, parallelogram, and trapezoid." In order to achieve this learning gain, the MoNE suggests the use of dynamic geometry software (TTKB, 2013). Participants were required to develop interactive instructional materials using GeoGebra based on the knowledge they gained through theoretical and practical lecture sessions. Participants also developed worksheets of their materials and lesson plans. They were required to perform student-centred microteaching sessions based on the lesson plan they developed.

During the first week of the semester, instructors introduced the course and provided general information about it. Participants were required to answer open-ended questions about computer-based mathematics education and to complete a TPACK survey. During the second week, mathematics education and technology, the use of technology in educational environments, and related theoretical concepts were introduced and discussed. The third and fourth weeks included introduction of GeoGebra software. Participants were taught GeoGebra software and developed basic and simple materials. Participants developed instructional materials using GeoGebra during the sixth, seventh, and eighth weeks. Microteaching sessions were performed during the ninth and tenth weeks. During the last week, participants answered the same open-ended questions and a TPACK survey. Table 1 presents information about the computer-based mathematics course's weekly schedule, learning gains, and targeted TPACK domain.

1st Week	The beginning of the course (24 February–3 March)	Introduction to the course, explain the syllabus, explain about the research, and answer open-ended questions and TPACK survey.	
	Assumptions	Learning Goals	Lesson Implementation (3 hours)
2nd Week	If pre-service teachers can explain CBME field and aims, development of their TPACK becomes positive	• Explain CBME • Explain aims of CBME	What is CBME? Is it necessary or not? How can it be implemented? What are the studies and examples from the world and Turkey?

3rd Week	If pre-service teachers know tools for mathematics education and can access software from correct sources, their attitudes and conceptions towards integration of technology into teaching and learning environments becomes positive.	• Know tools for mathematics education (software, web sites, etc.) • Know how to access tools for mathematics education	How is technology for teaching mathematics used? Discuss best cases and examples Investigate online resources and tools for mathematics education
4th, 5th Week	If pre-service teachers learn a dynamic geometry system (DGS) or computer algebra system (CAS), their attitudes and conceptions towards technology and using similar software in the future improve	• Define DGS and CAS • Identify DGS and CAS specific to teaching mathematics • Do mathematical operations (the four operations and drawing graphs and geometric shapes) using a DGS or CAS	What are DGS and CAS? What are the purposes of their use? Use Wiris software (online) as an example for CAS. Use Wiris for doing basic operations and exponential numbers, solving equations, and drawing graphs of functions in 2-D and 3-D. Use GeoGebra as an example for DGS. Installation of GeoGebra, introducing its interface and basic operations and investigating online examples and resources.
6th, 7th Week	If pre-service teachers have experience in developing appropriate instructional materials using DGS or CAS, their development of TPACK increases and they gain knowledge about integrating technology into classroom instruction in terms of technology, pedagogy, and content	• Solve mathematical problems related to mathematics content area using a DGS or CAS • Develop an instructional material	Recreate existing instructional materials using GeoGebra. Using slider tool, show/hide property and so on. Discovery learning session. Develop an instructional material using GeoGebra, targeting secondary school mathematics education learning gains. Discuss the quality of the developed materials.
8th, 9th Week	If pre-service teachers develop a study sheet appropriate to the target audience, write a lesson plan that explains how to use the study sheet and perform microteaching based on the material they developed and the study sheet, development of their TPACK increases. Thereby, integration of technology, pedagogy, and content knowledge is ensured. Eventually, a pre-service teachers' attitude, perception, and conception towards integration of technology into classroom instruction become more positive.	• Explain solution of a mathematical problem using DGS or CAS • Develop an instructional material using DGS or CAS • Write a lesson plan which includes use of the materials developed using DGS or CAS • Perform a microteaching utilizing the material developed using DGS or CAS	Develop study sheet and instructional materials using GeoGebra Develop a lesson plan and perform microteaching
10th Week	At the end of the course (12 May–20 May)	Take the TPACK survey and answer open-ended questions	

Table 1: Computer-Based Mathematics Course's Weekly Schedule.

Data Collection Tools
TPACK Survey

The TPACK survey was implemented to PSTs both before and after the 10 weeks of course implementation. Two Turkish-language TPACK surveys (Kaya & Dağ, 2013; Övez & Akyüz, 2013) were found based on the literature review. The two surveys overlapped in terms of grammatical language and meaning. Therefore, the survey developed by Kaya and Dağ (2013) was used in this study. The finalized survey used in this study included 28 items. Exploratory and confirmatory factor analyses conducted by Kaya and Dağ (2013) showed that the overall and sub-domains had alpha reliability coefficients between 0.77 and 0.88. The actual implementation of the survey in this study with 71 pre-service mathematics education teachers at the beginning of the course in this study was found to be 0.83 and at the end of the course it was found to be 0.94.

Interviews

A semi-structured interview form containing six main open-ended questions was developed to investigate PSTs' development of TPACK in detail. A mathematics education expert and a Turkish language expert investigated the form. After finalizing the form, two mathematics education teachers read the questions and confirmed their clarity. Table 2 presents the questions and their relationship with the TPACK framework. PSTs answered the questions at the beginning and at the end of the semester.

Question Item	**Relationship with TPACK framework**
How do you define computer-based mathematics education? What is the meaning of this concept for you? Please, explain it.	TPACK (theoretical) Technology knowledge Technological content knowledge
Do you know software or tools specific to mathematics education? If the answer is yes, please name the software you know and explain what can be done with that software? If the answer is no, is this a lack of professional knowledge? Is knowing such software a plus? Please, detail your answer. Did any of your instructors use technology in teaching mathematics? Please explain how they used technology.	Technology knowledge Technological content knowledge
Have you heard of the concepts DGS and CAS before? Can you define and explain them?	Technology knowledge
Can computers be used in teaching mathematics? If your answer is yes, can you explain how and why? Please provide an example. If your answer is no, can you explain why computers cannot be used for teaching mathematics?	TPACK (practical knowledge) Technological content knowledge
As a senior pre-service teacher, what do you lack in terms of using technology for teaching mathematics? Did this course contribute to your ability to use technology? What are your negative and positive opinions about this course?	TPACK (theoretical and practical)

Table 2: Open-Ended Questions and their Relationship with the TPACK Framework.

Microteaching Evaluation Scale

The microteaching evaluation scale (MTES), presented in Table 3 was developed by the researchers to obtain the information needed for the microteaching performances of the PSTs concerning TPACK and course gains.

Firstly, two researchers independently wrote their own assessment items according to the context of the course and the TPACK framework. They then came together and compared their items and gave final form to the evaluation scale based on their common view. While determining evaluation scale scores, it was considered that the importance of each criterion was equivalent. Therefore, each criterion was equally scored. MTES was used to standardize the evaluation process of microteaching based on the TPACK framework. The results of the microteaching scores and comments on their performance were shared with PSTs just after their microteaching session. The course instructor evaluated the PSTs' performances.

Evaluation Criteria	**Points**
Selecting appropriate learning gains from the instructional program (TCK)	0-20
Designing appropriate instructional method(s) for the learning gains (P and TPK)	0-20
Designing student-centred instructional activities (TPK, TCK)	0-20
Developing an appropriate dynamic geometry material (T, TCK)	0-20
Using the dynamic geometry system effectively (T, TCK, TPK and TPACK)	0-20
Total Score	**0-100**

Table 3: Microteaching Evaluation Scale.

Data Analysis

This research study used convergent parallel design as a parallel mixed method approach. The qualitative data sets, collected at the beginning and at the end of the course, were subjected to content analysis. The content analysis categories and themes were defined based on the TPACK framework, which was the theoretical base of this study. When there was a need, codes were renamed (Weber, 1990). The reliability of content analyses mostly depends on the coding process. Therefore, the coding process was carried by two researchers and their agreement percentage was calculated (Miles & Huberman, 1994) based on the formula agreement percentage = [agreement/(agreement + disagreement)] × 100. Ten qualitative data sets were selected randomly at the beginning of the data analysis. The researchers analysed the randomly selected data separately. The agreement percentage was found to be .94, which indicates a strong consistency and reliability for the data analysis process. To ensure validity issues regarding the qualitative phase, detailed information was provided about research purpose, information about participants and especially design of the course and process of implementation.

The quantitative data sets included the survey data collected at the beginning and at the end of the course implementation, which implied a pre-experimental design that included pre-test and post-test. First, lower bound values were calculated for the every single dimension of the survey based on the interval coefficient. The interval coefficient was calculated using the maximum total points obtainable on a five-point Likert scale (Tekin, 2001). Frequency distributions, percentiles, and means with standard deviations were presented based on the recalculation of points based on the lower bound limits. In order to test sub-research problems, which were designed to hypothesize whether there was a significant difference between pre- and post-test points in the TPACK survey, a Wilcoxon Signed-Rank Test was conducted. Kendall's tau_b and Spearman's correlation coefficient were calculated to analyse the relationship between the PSTs' pre- and post-test points and microteaching scores. A microteaching evaluation form is a kind of ordinal scale; therefore, Spearman's correlation test was used to analyse correlation. Kendall's tau_b test was used because the microteaching evaluation scores were dependent ordinal.

In this study non-parametric statistical analyses were conducted because both the pre- and post-test findings did not match the requirement of normality for some sub-dimensions. All of the statistical analyses were conducted at the 95% confidence interval and p = .05 significance level.

Findings and Discussions

At the beginning of the statistical analyses, a Mann Whitney U-test was conducted because the course implementations were carried out by different researchers, which required data sets from separate groups to be compared for equivalence of pre-test points of TPACK and sub-knowledge domains. As shown in Table 4, there were no significant differences between the two groups' pre-test points of TPACK and sub-knowledge domains (p > .05). This finding showed that the two groups were equivalent.

TPACK Domains	Group	Row Mean	Row Sum	U	*p
Technology (T)	Group 1	33.74	1282	-1,123	.262
	Group 2	38.61	1274		
Content (C)	Group 1	35.83	1361.50	-.083	.934
	Group 2	36.20	1194.50		
Pedagogy (P)	Group 1	34.66	1317	-.788	.431
	Group 2	37.55	1239		
PCK	Group 1	34.45	1309	-.757	.449
	Group 2	37.79	1247		
TCK	Group 1	33.92	1289	-.978	.328
	Group 2	38.39	1267		
TPK	Group 1	37.71	1433	-.883	.377
	Group 2	34.03	1123		
TPACK	Group 1	35.66	1355	-.173	.863
	Group 2	36.99	1201		

$^{*}p < .05$ $N_{Group\ 1} = 38$, $N_{Group\ 2} = 33$

Table 4: Mann Whitney u-test findings of pre-test points of TPACK and sub-knowledge domains.

Descriptive Findings about TPACK and Sub-Knowledge Domains

The first research question was "what are the PSTs' TPACK and sub-knowledge domain levels before and after the course implementation." Table 5 shows that PSTs were not confident in all sub-domains except Pedagogy Knowledge (76.1%) before course implementation. On the other hand, after course implementation they saw themselves as being confident in all sub-domains except PK. PSTs' confidence in themselves increased especially in Technology Knowledge (before: 49.3% after: 70.4%) and Technology Content Knowledge (before: 26.8% after: 63.4%).

Domains	Implementation	N	Strongly disagree (%)	Disagree (%)	Neither agree nor disagree (%)	Agree (%)	Strongly agree (%)	$\overline{X}$	Sd
Technology (T)	Pre-test	71	0	1.4	46.5	49.3	2.8	3.53	0.58
	Post-test	71	0	2.8	21.1	70.4	5.6	3.79	0.58
Content (C)	Pre-test	71	0	5.6	34.4	52.1	9.9	3.66	0.74
	Post-test	71	0	5.6	21.1	62.0	11.3	3.79	0.72
Pedagogy (P)	Pre-test	71	0	0	9.9	76.1	14.1	4.04	0.49
	Post-test	71	0	1.4	4.2	73.2	21.1	4.14	0.54
PCK	Pre-test	71	0	5.6	29.6	54.9	9.9	3.69	0.73
	Post-test	71	1.4	4.2	25.4	59.2	9.9	3.71	0.76
TCK	Pre-test	71	1.4	23.9	46.5	26.8	1.4	3.02	0.79
	Post-test	71	0	8.5	25.4	63.4	2.8	3.61	0.69
TPK	Pre-test	71	1.4	1.4	29.6	63.4	4.2	3.68	0.65
	Post-test	71	0	1.4	12.7	74.6	11.3	3.96	0.55
TPACK	Pre-test	71	1.4	1.4	33.8	59.2	4.2	3.63	0.66
	Post-test	71	0	0	19.7	67.6	12.7	3.93	0.57

*$p < .05$ $N_{Group\ 1} = 38$, $N_{Group\ 2} = 33$

Table 5: Descriptive Findings about TPACK and Sub-knowledge Domains.

Qualitative findings from the interviews supported the data above. At the beginning of the course, most PSTs were not able to correctly define terms related to CBME and teaching with technology. For example, one pre-service teacher provided a superficial definition, “using computers in mathematics education is to develop materials” [PST-64], while another overemphasized the technology, “using smart boards and tablets for lesson implementations” [PST-33]. When quantified, 29 PSTs’ answers were coded under “using computers and technology (e.g., smart boards, internet, and projection) for teaching mathematics.” Fourteen PSTs did not answer this question. The following excerpts shown in Table 6 present PSTs’ conceptions about CBME before and after the course implementation

Before:	After:
Computer-based mathematics is enriching a mathematics course with technology. [PST-38]	Using all kinds of technology for teaching mathematics to increase the quality of instruction, to provide instruction that can be understood easily, and to benefit and increase visualization capabilities. [PST-38]
CBM is the intersection of mathematics and technology. Using smart boards, tablets, and computers for presenting information to students. [PST-10]	Using the internet and software for our instructional environment to teach mathematics, thereby students are going to be actively involved in classroom instruction and their learning will be more permanent. [PST-10]
Use of technology in mathematics courses. [PST-31]	Getting the students’ attention can be the first aim. Then CBM can ensure students’ active participation in learning-teaching processes. Indeed, students should have active roles during most of the class instead of the teacher. [PST-31]
CBM is the set of software developed in order to use technology to teach mathematics. [PST-41]	CBM is the use of computers and technologies for classroom instruction in order to have a student-centred learning environment so that students participate more actively. CBM also provides visualization. [PST-41]

Table 6: Comparisons of the student responses before and after the course defining terms related to CBME and teaching with technology

The concept of “teaching with technology/computers” was included in the definitions at 17.1% (f = 22) before the course implementation and it increased to 24.6% (f = 44) after the course implementation. Similarly, the statement “using computers for better learning” was 9.3% (f = 12) before the course implementation and 20.1% (f = 36) after the course implementation. Finally, the “using software or tools” theme was stated by 8.5% (f = 11) and 12.8% (f = 23), respectively, before and after the course implementation. The themes “visualization and reification via technology” (before: 12.4%, after: 10.6%) and “enjoyable teaching via technology” (before: 6.2%, after: 3.4%) did not differ too much before and after. Table 6 presents the themes of PSTs’ total conceptions before and after the course implementation. Participants provided limited definitions before the course on the other hand they provided more detailed definitions after the course. This situation can be seen in Table 7 by comparing the numbers corresponding “Very superficial or blank answers” before the course (31.0%) and after the course (6.1%).

Definition	**Before the Course Code (%)**	**After the Course Code (%)**
Very superficial or blank answers	40 (31.0%)	11 (6.1%)
Teaching with technology/computers	22 (17.1%)	44 (24.6%)
Visualization and reification via technology	16 (12.4%)	19 (10.6%)
Using computers for better learning	12 (9.3%)	36 (28.0%)
Using software or tools	11 (8.5%)	23 (12.8%)
Enjoyable teaching via technology	8 (6.2%)	6 (3.4%)
CBM defined as tutorial	7 (5.4%)	2 (1.1%)
Teaching with active participation	2 (1.6%)	25 (14.0%)
Using computers to get attention	2 (1.6%)	2 (1.1%)
CBM could cause injustice	0 (0.0%)	3 (1.7%)
Considering different learning styles	0 (0.0%)	2(1.1%)
Other (saving time, preparing presentations, drill and practice, teaching with tablets and smart boards)	9 (7.0%)	6 (3.4%)
Total	129 (100%)	179 (100%)

Table 7: Pre-service teachers’ definitions before and after the course implementation

Comparison of Pre-Service Teachers’ Pre-Test and Post-Test Points of TPACK

The second research question tried to answer whether there was a significant difference between PSTs’ TPACK and sub-knowledge domain levels before and after the course implementation. Table 8 presents the findings of the Wilcoxon Signed-Rank Test. Findings show that there were significant differences in favour of the post-test points for TPACK ($z = -2{,}960$, $p < .05$) in general and for the sub-domains T ($z = -2{,}874$, $p < .05$), TCK ($z = -4{,}341$, $p < .05$), and TPK ($z = -2{,}655$, $p < .05$). When the row-mean and row-sum of difference scores are taken into consideration the observed difference is in favour of positive rows concerning T, TCK, TPK and TPACK domains. In other words it is in favour of the post-test. These findings indicate that the course implementation affected PSTs’ development of TPACK in general and the T, TCK, and TPK domains positively.

Domains	Pre-test – Post-test	N	Row Mean	Row Sum	Z	p*
Technology (T)	Negative row	16	18.94	98.00		
	Positive row	19	17.21	337.00	-2.874	.004*
	Equal	36				
Content (C)	Negative row	12	14.71	176.50		
	Positive row	18	16.03	288.50	-1.253	.210
	Equal	41				
Pedagogy (P)	Negative row	8	11.38	91.00		
	Positive row	14	11.57	162.00	-1.251	.211
	Equal	49				
PCK	Negative row	16	18.94	303.00		
	Positive row	19	17.21	327.00	-0.207	.836
	Equal	36				
TCK	Negative row	7	18.50	129.50		
	Positive row	36	22.68	816.5	-4.341	.000*
	Equal	28				
TPK	Negative row	9	15.78	142.00		
	Positive row	24	17.46	419.00	-2.655	.008*
	Equal	38				
TPACK	Negative row	8	13.50	108.00		
	Positive row	23	16.87	388.00	-2.960	.003*
	Equal	40				

Negative row: post-test < pre-test, Positive row: post-test > pre-test, Equal: post-test = pre-test; *p < .05

Table 8: Findings of pre-test and post-test points of tpack and sub-knowledge domains

Qualitative findings indicated that PSTs did not have any experience teaching with technology except the use of PowerPoint (83.1%), and they were aware that it was necessary to develop skills in teaching with technology (f = 53.5%) before the course implementation. Nearly all of the PSTs (93.0%) stated that they had not heard the terms DGS and CAS before the course, but after the course 45.1% had. In other words, only 6 PSTs (8.5%) indicated that they heard the terms before the course and 45 PSTs (63.4%) stated that they knew the terms after the course. The terms were directly related to course content and the terms were explained during the theoretical lecture sessions; however, the percentage of PSTs stating that they heard the terms after the course was lower than expected. The reason for this low percentage might be that PSTs valued GeoGebra and Wiris more than theoretical knowledge and definitions. A support for this argumentation may be that 65 (91.5%) PSTs indicated that they knew software and tools specific to teaching mathematics after the course. At the beginning of the semester 64 PSTs (90.1%) indicated that they did not know any software for teaching mathematics. Table 9 presents the excerpts which show that PSTs were not familiar with software specific to teaching mathematics before the course.

Before:	After:
I don’t have enough knowledge and our instructors didn’t use such software; therefore, I don’t know software for mathematics. [PST-62]	I think that GeoGebra, which we learnt this semester, is very useful and effective for teaching mathematics. I wish we could have had the chance to learn similar software before. [PST-62]
No answer. [PST-40]	For example, GeoGebra. We can use it in teaching geometry. I am going to us it for subjects related to geometry. [PST-40]
No answer. [PST-26]	I think that GeoGebra can be used only in geometry. On the other hand Wiris can be used for algebra, preparing examinations, and

	even geometry. I believe that Wiris is more useful than GeoGebra because it is easier to use. [PST-26]
I didn't hear. [PST-14]	I heard about GeoGebra (DGS) during this course and I used it. It is software that can be used to develop materials related to geometry. CAS covers software related to algebra. [PST-14]
I am not competent in using technology in classroom. I like technology and want to use it. I want to use technology while I'm teaching. I'm going to develop myself. [PST-17]	I was not competent in using these before taking this course. But now I'm confident that I can use such technology in my instruction. [PST-17]

Table 9: Comparisons of the student responses before and after the course defining terms related to teaching with technology

Comparison of Pre-Service Teachers' Pre-Test and Post-Test Points of TPACK and Microteaching Scores

The third research question aimed to determine whether there was a relationship between PSTs' microteaching scores and TPACK points before and after the course implementation. Kendall's tau_b and Spearman's correlation coefficient were calculated to analyse the relationship between the PSTs' pre- and post-test points of TPACK and microteaching scores. As Table 10 shows, there was no significant relationship between pre-test points of TPACK and microteaching scores. On the other hand, there are significant relationships between microteaching scores and post-test points of TPACK in general, C, PCK, and TPK. There are significant relationships between microteaching scores and Content (Kendall's tau_b [$r = 0,232$, $p < .05$] and Pearson's rho [$r = 0,290$, $p < .05$]), between microteaching scores and Pedagogical Content Knowledge (Kendall's tau_b [$r = 0,241$, $p < .05$] and Pearson's rho [$r = 0,290$, $p < .01$]), between microteaching scores and Technological Pedagogical Knowledge (Kendall's tau_b [$r = 0,231$, $p < .05$] and Pearson's rho [$r = 0,288$, $p < .05$]), and between microteaching scores and TPACK in general (Kendall's tau_b [$r = 0,289$, $p < .01$] and Pearson's rho [$r = 0,362$, $p < .01$]).

There were weak correlations between microteaching scores and C, PCK, and TPK as the reported r values for the correlations were between .10 and .29 (Cohen, 1988) and there was a medium correlation between microteaching scores and TPACK in general, which confirms the TPACK theoretical framework. There was no significant relationship between microteaching scores and pre-test points but there was a moderate relationship between microteaching scores and post-test points concerning TPACK, which indicated that the implemented course affected PSTs positively in terms of their development of TPACK.

Domains	Test	Correlations	Microteaching Score Kendall's tau_b	Spearman's rho
Technology (T)	Pre-test	r	-0.049	-0.061
		p	0.615	0.612
	Post-test	r	0.05	0.064
		p	0.605	0.595
Content (C)	Pre-test	r	0.082	0.102
		p	0.385	0.398
	Post-test	r	.232(*)	.290(*)
		p	0.015	0.014
Pedagogy (P)	Pre-test	r	0.081	0.106

		p	0.403	0.377
	Post-test	r	0.099	0.125
		p	0.311	0.299
PCK	Pre-test	r	0.054	0.07
		p	0.568	0.559
	Post-test	r	.241(*)	.308(**)
		p	0.011	0.009
TCK	Pre-test	r	-0.017	-0.015
		p	0.86	0.903
	Post-test	r	0.174	0.218
		p	0.071	0.068
TPK	Pre-test	r	0.025	0.032
		p	0.796	0.79
	Post-test	r	.231(*)	.288(*)
		p	0.017	0.015
TPACK	Pre-test	r	-0.015	-0.017
		p	0.877	0.886
	Post-test	r	.289(**)	.362(**)
		p	0.003	0.002

*p < .05; **p < .01; N = 71

Table 10: Findings of Kendall's tau_b and Spearman's correlation tests of pre-test and post-test points of TPACK and microteaching scores

The findings showed that the course implementation developed PSTs' TPACK. The correlations between microteaching scores and post-test points of C, PCK, TPK, and TPACK indicated that PSTs who have deeper knowledge and experience in teaching with technology also had higher points for TPACK, TPK, PCK, and C. The increase and the relationship with Content Knowledge base may indicate that PSTs learnt their content while developing materials through learning by doing. PSTs clearly identified the importance of experiencing teaching with technology, as shown in the statements below:

> After: Using technology for teaching mathematics should be demonstrated to pre-service teachers. There should be more courses like this one. [PST-06]
>
> After: Pre-service teachers should be given chance to practice teaching with technology thereby they will have experience in how to use technology for classroom instruction. [PST-21]
>
> After: I'm taking this course as a senior student, but courses like this one should have been offered in previous semesters. There should be more microteaching activities like we did last week. [PST-31]

Pre-Service Teachers' Conceptions of Learning and Teaching with Technology

PSTs' conceptions of learning and teaching with technology were analysed in two dimensions: before and after the TPACK-based course implementation. In order to reveal their knowledge about CBME, DGS, and CAS, PSTs were asked questions such as, "What is computer-based mathematics education? Can you explain it?" To reveal their experiences about integrating technology with mathematics education, the following questions were asked: "Did you take any courses that integrated technology with classroom instruction?" and "Did you prepare any technology-based material to teach mathematics with technology before? If your answer is yes, please describe the material you developed." Finally, PSTs were asked "As a senior pre-service teacher, please state what you lack regarding the use of technology for classroom instruction." and "What should be done to have teachers who are able to effectively teach with technology?"

Qualitative results showed that PSTs had knowledge about their content area and pedagogy at an intermediate level. Their technology knowledge was at entry level before the course implementation. Most of them indicated that they had not heard of GeoGebra, Wiris, or any other software that could be used in teaching mathematics. Most of them listed PowerPoint as the technology that can be used while teaching mathematics with technology and the purpose of using it would be to show pictures of shapes, formulas, etc. On the other hand, after the course implementation they became aware of software such as GeoGebra, which they used to develop instructional materials; Wiris; and some others that were discussed during the lessons. For example, after the course one PSTs described the relationship between content knowledge and technology knowledge sub-domains of TPACK by stating, "Mathematics teachers should know mathematics very well. They have to have very good mathematical knowledge. Afterwards, they can learn how to integrate technology into mathematics teaching" [PST-37].

Another pre-service teacher underlined the importance of pedagogy and technology as "technology-based courses are only in first year and fourth year and this is not enough. There should be more courses like these at other levels of our education" [PST-52]. It is worth noting that there were 10 PSTs who indicated the exact same thing: that there should be more courses like CBME.

As expected, most PSTs' awareness about teaching with technology in general increased, but it was significant that the focus point of this awareness was using technology (f = 38). The PSTs learnt GeoGebra for two weeks and developed their instructional materials using Geobebra for three weeks. Therefore, their answers involved technology, including software, more than other knowledge bases. The following excerpts showed that the implementations affected PSTs' conceptions about teaching and learning with technology:

> After: At the beginning of the semester I thought that I did not have enough knowledge. However, I can say that I can use technology for my classroom instruction based on the knowledge and experience from this course. Of course, I'm going to develop myself. [PST-32]
>
> After: I didn't know the software related with my content area. This course increased my awareness about such software. After completing this course, I now know that there is software that can be used in teaching mathematics. I'm not an expert user but I know the basics. [PST-21]

Conclusions and Recommendations

The implemented instructional process positively supported PSTs' development of TPACK; in particular, their TK, TCK, and TPK increased. This conclusion supports the literature, which has indicated that courses designed based on a TPACK framework increase PSTs' development of TPACK (Balgalmis et al., 2014; Haciomeroglu et al., 2009; Meagher et al., 2011).

PSTs did not have confidence in their knowledge of TPACK domains except pedagogy before the course implementation. Pamuk, Ülken, and Dilek (2012) had similar findings where although PSTs believed that they had pedagogical knowledge, they did not have the necessary knowledge and skills to integrate technology into instruction effectively.

After our course implementation PSTs' knowledge about other domains of TPACK increased, which is similar to Pamuk et al.'s (2012) results.

PSTs stated that the course contributed to their development and that similar courses should be offered in earlier semesters of their educational programs. The contribution of the course to PSTs can be seen from the increase in their competence in defining computer-based mathematics education concepts (TCK) and the statistical findings, which indicated that there are significant differences between PSTs' pre- and post-test points in TPACK, T, TCK, and TPK. Wakwinji's study (2011) showed that such courses develop PSTs' Technology, Technological Content, and Technological Pedagogical Knowledge sub-domains in ways similar to the our findings. This study revealed that if PSTs do not observe and experience use of technology for instruction via their undergraduate courses, they do not have the Technological Knowledge. In other words, such courses directly contribute their Technological Knowledge domain. Therefore, this study supports the findings of Balgalmis et al. (2014), who stated that producing content and using tools affects PSTs' TCK.

There were weak but significant relationships between microteaching scores and post-test points of C, PCK, TPK, and there were medium and significant relationship between microteaching scores and TPACK. The course implementation process helped PSTs gain knowledge and experience about the technology they used and how to use that technology in their classroom instruction. This process had a positive effect on their microteaching scores and development of TPACK. In other words, PSTs who internalized teaching with technology performed well in their microteaching, thereby getting higher grades and having higher points for TPACK. Meagher, Özgün-Koca, and Edwards (2011) and Haciomeroglu et al. (2009) also reported similar results, showing that when teachers' teaching experience increased their development of TPACK also increased. In order to give PSTs' more experience in technology-based learning environments, courses that integrate technology into classroom instruction or teach how to integrate technology should be offered in various semesters of their pre-service education programs.

There was also a similar finding related to teachers' familiarity with and use of specific software and tools for teaching mathematics (T and TCK). A comparison of PSTs' opinions about the use of computers for mathematics education in terms of teaching purpose, phase of a lesson, and learning gain targeted showed that their development of TPK was affected positively. The main reason for this result was the design of the implemented course. The implemented course required PSTs to not only develop instructional material but also to use that material for classroom instruction in a microteaching session. With this requirement, PSTs were required to plan how to use their material for their class-room instruction. Haciomeroglu et al. (2009) reported that when PSTs' teaching experience increased their TPACK also increased.

As a final word, our study showed that a CBM course contributed to PSTs' development of TPACK, especially in the T, TCK, and TPK sub-domains. The main reason for this significant result was that PSTs neither learnt about nor observed and experienced these technologies during their undergraduate education. Instructors of faculties of education should not only use technology in their instructional environments for presentation purposes but also give PSTs hands-on experience. In other words, PSTs should be shown how to effectively integrate technology into teaching/learning processes so that they can observe the expected use of technology: "Activities such as faculty modelling could better support these initial stages of teachers' TPACK formation" (Koh & Divaharan, 2013, p. 244). Faculties of education in Turkey offer obligatory courses such as Computer 1, Computer 2, and Instructional Technologies and Material Development. PSTs have learnt theoretical knowledge at most or they have learnt technology-oriented course content separate from their content area knowledge (Alayyar, Fisser, & Voogt, 2012). This has been the reason why

PSTs lack the necessary experience in using technology in their content area for teaching and instructional purposes. Therefore, PSTs should be offered similar courses during earlier semesters of their educational programs. There should be more courses that require PSTs to develop computer-based instructional materials and then use these materials for instruction with microteaching sessions.

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