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Research Article

Development of TPACK with Web 2.0 tools: Design-based study

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ABSTRACT

This mixed-method study, which aimed to examine the development of teacher candidates, was organized as a design-based study. During the 14-week instructional sequence, pre-service teachers were given training based on the designed hypothetical learning trajectory. The data collected through the lesson plans before and after the training and interviews were organized and analyzed by using the rubric prepared within the scope of Web 2.0 tools by the researchers. Moreover, the pre-training and post-training scores obtained using this performance rubric were analyzed with the related sample t-test. In addition, learning packages and interviews were analyzed using content analysis technique. The findings showed that there was an improvement in the technological pedagogical content knowledge of the pre-service mathematics teachers with the training provided for the use of Web 2.0 tools in mathematics education. In the study, an alternative educational content that can be used in lessons related to instructional technologies in undergraduate programs that train mathematics teachers has been prepared.

Keywords: design-based research, pre-service mathematics teachers, Web 2.0 tools, technological pedagogical content knowledge

INTRODUCTION

Web 2.0 tools have started to gain a place in the field of education since in learning environments, which are supported with Web 2.0, students have not only passive roles such as readers or viewers like in traditional learning environments, but also take active roles such as editing and producing learning materials. These tools can also be effective learning tools in mathematics lessons in terms of designing various and useful learning materials and multiple representations of concepts by providing enhanced learning opportunities to students. However, using these tools in the lessons is related to teachers' knowledge about how to use them. Similarly, inclusion of these tools in the lesson plans and curriculum do not guarantee that Web 2.0 tools are successfully integrated into the mathematics lessons. Integration of Web 2.0 tools into mathematics lessons is related to teachers' knowledge and beliefs regarding these tools because supporting the learning process using these tools relies on how much knowledge teachers have to use them, how they make connection between these tools and mathematical concepts and how they use these tolls in order to enhance pedagogical skills. The related studies in the literature have supported this issue and emphasized the need to focus on technology integration on learning environments through gaining necessary knowledge and experience for in-service and pre-service teachers (Mudzimiri, 2012; Niess, 2005; Niess et al., 2009). In other words, acquiring the necessary knowledge and experience about how to integrate technological tools into lessons while teaching specific mathematical concepts has great importance for them. At this point, teacher education programs, which are institutions that provide teacher education, are of great importance in terms of providing pre-service mathematics teachers (PMTs) with the knowledge and experience that will enable this integration effectively (Angeli & Valanides, 2009; Chai, 2019; Chai et al., 2010; Mouza et al., 2014; Niess, 2005).

Considering the role of technology in all parts of daily life and current mathematics curriculum, teachers are expected to use technology in their lessons, adapt it to their lessons, and provide their students with learning opportunities that will support their use of technology. Therefore, many studies have focused on the development of technological pedagogical content knowledge (TPACK) of teachers and pre-service teachers. Niess (2005) defines TPACK as teachers' support of students' learning by effectively integrating current technology into their lessons while planning and applying their lessons. With this knowledge, the teachers can ensure that the students, technology, and course content in the education process become consistent in an interactive and dynamic way. According to Mishra and Koehler (2006), the TPACK model explains the degree of teachers' technology integration with their lessons. The TPACK model includes content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological knowledge (TK), technological content knowledge (TCK), and technological pedagogical knowledge (TPK) and their interaction as TPACK. According to this model, effective integration of technology into a learning environment relies on not only the teacher's knowledge about the content or its possible teaching methods but also knowledge about using the most suitable technological tool in a more appropriate way for this content and teaching method (Mishra & Kohler, 2009; Niess, 2005). Based on the idea that technology added to the concept of PCK with TPACK can be used as a pedagogical tool, it emerges as a different type of knowledge with the interaction of TK and these types of knowledge (Koehler & Mishra, 2009). In terms of mathematics education, it can be seen that the type of knowledge that stands out when a mathematics teacher uses a technological tools to support his teaching environment, methods and techniques while teaching mathematics subjects to the students, it emerges from technology knowledge integrated with PCK (Jang & Chen, 2010).

The studies in the literature related to the TPACK model show that teachers with a high level of TPACK can use technology consciously and coherently in their lessons so that they can teach more effectively by utilizing necessary tools and methods how students can learn better with the help of technology (Niess, 2011; Preiner, 2008). Similarly, it is seen that teachers who use this knowledge model effectively can create rich learning environments offering various technological opportunities (NCATE, 2012; Niess et al., 2009). For this reason, the related studies generally agree on providing teaching and learning experiences to pre-service teachers through teacher training process. Their education holds an important place for their future professional development and fosters TPACK of them so that they will effectively perform their lessons using technology when they become teachers in the future (Angeli & Valanides, 2009; Chai et al., 2010; Koehler & Mishra, 2009; Mouza et al., 2014; Niess, 2005). In other words, if pre-service teachers understand and comprehend not only usage of technology alone but also its usage in learning environment for specific contexts, it can be ensured that they will become teachers who can use technology in their professional lives and reflect its benefits on their learning environments (Kinuthia et al., 2010). Similarly, Albion (2008) emphasizes that the use of Web 2.0 tools in teacher education programs can be beneficial in their professional development.

Technological Advances in Learning Environments Through Web 2.0 Tools

The recent developments on technology and its commonly usage require teacher candidates as professionals to be able to use TPACK interactively in their professional development. The recent studies focus on designing learning and teaching activities in a way that makes students active, regardless of time and place, in a way supporting students' lifelong learning and out-of-school learning environments (Belland, 2009; Hew & Brush, 2007). The idea that these activities can benefit from the convenience and opportunities offered by technological tools paved the way for the use of these tools in the field of education. For example, the ability of Web 2.0 tools to access and modify a large repository of information such as images, text, map data, tables and search indexes are important features that can be used in education. Web 2.0 tools offer such opportunities that can support the development of new pedagogies in the process of transferring course content to students and that students can carry out learning activities whenever they want. The research investigating the use of Web 2.0 tools in education emphasize that the use of these tools in the education process in a way that supports teaching ensures that the learning activities can be continued regardless of time and place so on retainable learning could take place (Belland, 2009; Hew & Brush, 2007; Wang & Woo, 2007). Moreover, Web 2.0 tools can provide such opportunities for students to perform their creativity while producing, evaluating, and organizing information in an interactive process of learning (Richardson, 2009). In addition, these tools are internet-based systems so they could support learning environments by providing social interactions among students across the world via blogs, discussion boards, audio/video chat, file sharing, social media platforms, interactive whiteboards, and wikis. Therefore, Web 2.0 tools also offer various teaching opportunities for teachers as in the pedagogical context such as sharing information with students, evaluating their performance, communicating, and collaborating with students, and sharing audio/video recording of lesson periods (Velagapudi, 2013). Hence, Web 2.0 tools can provide a harmonious interaction between teacher, student, and course content. Greenhow (2007) highlights the impact of Web 2.0 tools on this interaction by stating that they "facilitate increased interaction and networking and co-creation of content among teachers, students, and others" (p. 1990).

Web 2.0 tools can effectively be used in creating environments as well as in designing learning environments based on social constructivism by supporting student learning, since these tools make it easier to get feedback on students' actions and development in these environments and to provide them necessary information regarding these feedbacks (Ferdig, 2007; Harrison & Thomas, 2009). The research have summarized the benefits of Web 2.0 tools in the field of education, as follows:

(a) creating learning communities and also accessing students' roles and responsibilities in these communities, reviewing learning, and teaching process, organizing, and evaluating information and providing feedback,

(b) providing opportunities for interaction independent of time and place by creating learning communities in out-of-school learning environments,

(c) using different sources to access and verify information,

(d) provide easy-to-use tools for the protection of personal data, and

(e) revealing, discussing, and evaluating different perspectives, supporting professional development, and sharing professional experiences regardless of time and place (Ferdig, 2007; Grosseck, 2009; Harris & Rea, 2009; Harrison & Thomas, 2009; Jakes, 2007).

Web 2.0 Tools in Mathematics Education

Technological developments bring novel ways of educational situations. Much software have been designed for mathematics teaching and their use has shifted mathematics education in static mode to a more dynamic and funnier environment for learning needs of students (Hossain & Wiest, 2011). Technological tools not only help teaching and learning mathematics, but also provide great convenience to teachers, students, or administrators such as electronically collecting, recording, organizing, analyzing paper-based data, and easily sharing it with other groups such as parents (Kimmins, 1995). At this point, the rapid growth of internet and mobile technologies has led to development of interactable Web 2.0 tools for teaching-learning mathematics as derivative of classical mathematics software such as Terrapin Logo, GeoGebra, Geometry Expressions, Geometer's Sketchpad, Fathom, My Mathematical Life, Math Arena Advanced, Data Explorer, TI-84 Graphing (Garofalo et al., 2000). For example, GeoGebra has become a kind of Web 2.0 tool as well as Geometry Expressions Software. Therefore, students and teachers have begun to work with these mathematical tools collaboratively and coherently by sharing ideas, expressing their works to others, giving feedback and so on. The purposes and ways of using Web 2.0 tools in teaching-learning mathematics can be grouped as follows: mathematical concept and skill development, mathematical problem solving, mathematical reasoning and proof and mathematical communication (Kimmins, 1995; Kimmins & Bouldin, 1996).

NCTM (2000) emphasizes the integration of technology into lessons in all processes of mathematics lessons from planning what is taught to evaluating what is learned (Powers & Blubaugh, 2005). Web 2.0 tools can be used effectively in mathematics education considering this suggestion of NCTM (2000) since Web 2.0 tools can provide convenient, accurate and dynamic learning tools to construct graphics and drawings easily as well as provide enhanced computational power in mathematics lessons, and shared learning experiences for students and teachers. In addition, these tools enable students to engage in learning environments where mathematical ideas are compared and discussed in the classroom or in out-of-school environments, and mathematical content could be easily connected with real-life environments. The importance of supporting the mathematical content with appropriate pedagogical methods is a necessity to provide effective mathematics learning to students (Shapira & Zavelevsky, 2019). Web 2.0 tools can provide such environments for students to encourage this issue in order to enhance learning and their achievement in mathematics lessons by adding effective communication and real time interaction among peers on virtual tools (Bustamante, 2017).

Bustamante (2017) states that Web 2.0 tools can be an effective pedagogical method that can be used as mathematical learning activities. Similarly, studies on the integration of Web 2.0 tools into lessons show that these tools are one of the teaching tools and methods interiorized by mathematics teachers, and the usage of these tools in mathematics lessons has been able to change the perceptions of students, especially who are not interested in mathematics, and increase their motivation (Ng et al., 2019). The research related to using various Web 2.0 tools in lessons have revealed the positive effects of these tools for mathematics learning environment. For example, using Padlet, a kind of Web 2.0 tool, in mathematics lessons has been seen as beneficial to provide an effective environment by encouraging interaction for students to share their ideas easily and make discussions about the context while dealing with problem solving situations (Haris et al., 2017). In addition, Karaoglan-Yilmaz et al. (2018) have observed that the digital stories created by using Web 2.0 tools can make mathematical concepts more concrete and interesting, and thus students' misconceptions could be eliminated. Therefore, the use of Web 2.0 tools in mathematics lessons can transform lessons into more interesting and fun, and thus negative perceptions towards mathematics can be changed (Graham et al., 2018). However, the use of these tools in the lessons and taking advantage of them in the learning environments, relies on teachers' knowledge about how to integrate them in teaching mathematics content and using suitable pedagogy.

Motivation of the Study

There are research in the literature emphasizing the use of Web 2.0 tools to support the professional development of pre-service teachers in terms of facilitating their knowledge about using in education for teaching purposes (Parkes & Kajder, 2010; Sengur, 2020). These studies show that Web 2.0 tools can be taught in teacher training programs in the form of gaining experiences and preparing learning situations with these tools to provide pre-service teachers to learn in the process of preparing tools for teaching. In these studies, Web 2.0 tools that support collaborative and group work were frequently used (Hinduja & Patchin, 2008; Parkes & Kajder, 2010; Richardson, 2009; Wheeler, 2009). Moreover, the research revealed that Web 2.0 tools affect gaining intuitions for high-level thinking domains such as critical and reflective thinking, and providing information sharing, communicating and interaction between student-teacher or teachers (Ajjan & Harsthone, 2008; Jones et al., 2010; Kop, 2007; Parkes & Kajder, 2010; Wopereis et al., 2010; Yang, 2009). Therefore, it has been suggested that providing pre-service teachers to learn enhanced by Web 2.0 tools in their university courses can help them to understand the way of effectively integrating these tools into their future lessons (Loving et al., 2007). Moreover, it has been observed in previous research utilizing these tools in their university courses enables pre-service teachers to develop positive attitudes towards teaching with them in their future professional lives and increase their motivation towards technology integration (Mazer et al., 2007; Ray & Hocutt, 2006).

Although the positive effects and benefits of Web 2.0 tools are emphasized in the research, it has been revealed that using them for teaching purposes is still not at the expected level in the integration of technology into the lessons and is not used as often or effectively as necessary (Powers & Blubaugh, 2005). The research of Kurz and Middleton (2006) show that PMTs do not have enough experience in the integration of technological software and tools in teaching-learning processes when they graduate. In addition, Smith and Shotsberger (2001) have observed in their study that although many of the PMTs are aware of the importance of using technology in mathematics education, they lack knowledge about the use of these software and tools and their integration into lessons, so they avoid applying and discussing it in their teaching environments upon graduation. For this reason, it has been stated in previous research that these PMTs' readiness to use technology while teaching mathematics is not at a sufficient level when they graduate unless they receive suitable and coherent experiences in their teacher training programs (Carlson & Gooden, 1999; Habre & Grunmeier, 2007; Terri, 2011). The reason for this could be stated that pre-service teachers sometimes could focus on just the usage of technological tools by ignoring the course content and pedagogical situations in technology supported lessons (Istenic Starčič et al., 2016; Samaras & Fox, 2013). For this reason, it is of great importance to acquire not only TK but also pedagogical and CK while experiencing how to integrate technology in the context of teaching and learning. At this point, education of pre-service teachers are of great importance in terms of obtaining the knowledge and experience about these integration of technology (Angeli & Valanides, 2009; Chai et al., 2010; Mouza et al., 2014; Niess, 2005). For this reason, it is important to obtain the necessary knowledge and experience for the integration of Web 2.0 tools for PMT before they graduate. Technological tools could be considered only as a tool and cannot be used to teach mathematics in lessons if the teacher ignores the mathematical content and pedagogical aspects of the course. In this respect, it is important for PMTs' professional development to use their TPACK interactively with the help of Web 2.0 tools.

The main purpose of this study is to provide ways PMTs to gain experiences with Web 2.0 tools and to foster their TPACK throughout these experiences. By this way, it was aimed to provide them such experiences to increase their awareness of various technological tools that can be used in mathematics education, and to gain a perspective on how these technological tools can be integrated into mathematics lessons. In other words, in this study, it was aimed to develop the TPACK of PMTs using Web 2.0 tools and to examine this development process. For this reason, answers to the following research problems were examined in the present study:

1. What are the PMTs' levels of TPACK that they utilize while preparing learning environments before and after participating in Web 2.0 tools training?
2. Is there a change in PMTs' level of TPACK that they utilized while preparing learning environments before and after participating in Web 2.0 tools training?
3. How does the hypothetical learning trajectory (HLT) designed for using Web 2.0 tools support PMTs in developing their TPACK?

METHOD

This study was designed to enable PMTs to design lessons using Web 2.0 tools, to help them acquire the TPACK necessitated in designing technology integrated learning environments, and to help them gain experience in using this knowledge in practice. This design-based research was conducted within the scope of an elective computer-assisted mathematics teaching course focusing on how to use and apply Web 2.0 tools into mathematics learning environments. In this context, HLT lasting fourteen weeks was designed, and the instructional sequence guided based on this HLT. Thus, the instructional sequence combining theory and practice for this course was designed, tested, and re-arranged in line with the analysis and finalized. This study, as suggested by Wubbels (2007), focused on teaching how to integrate Web 2.0 tools in learning situations by encouraging students' learning rather than just technically using Web 2.0 tools.

The present design-based research was made by the explanatory sequential mixed design as one of the mixed research design, analyzing qualitative and quantitative data together, was used in order to represent the effect of instructional sequence performed based the designed HLT related to Web 2.0 tools on the pre-service teachers' TPACK. In this mixed research design, by diversifying the data, quantitative data acquired by scoring the lesson plans using the adapted form of TPACK were initially analyzed, and then qualitative data acquired through descriptive analysis of lesson plans based on TPACK and interviews were analyzed in order to interpret the initial quantitative data more detailed and effectively.

Design-Based Research

This study aiming to examine the development of pre-service teachers was organized as a design-based research. Design-based research can be defined as an approach that examines and explains learning and teaching in natural settings by combining theory and practice, describing a series of steps taken to produce new theories, artefacts and practices that potentially affect them. This design-based study consisted of the preparation, implementation and evaluation of a fourteen-week learning route.

Design-based research involves organizing several important types of learning. It is a research design that promotes learning by systematically presenting contextual contents and tasks to learners while providing opportunities for testing these contents and tasks. In this way, it is possible to develop theories about the learning processes of individuals. The theory, which is formed in this way and explains the learning processes of individuals, aims to explain the patterns and models in which learning occurs with the help of tools or tasks that promote learning. In addition, design-based research provides a deep and effective understanding for investigating learning that takes place based on the learning environment and instructional sequence (Cobb et al., 2003). In the light of these explanations, design-based studies can be defined as "a set of approaches to produce new theories, artifacts and practices that explain and potentially affect learning and teaching in natural settings" (Barab & Squire, 2004, p. 2).

Design-based studies focus on the practitioner's intervention in the learning process by being implemented in real environments where teaching takes place. In other words, the learning process is intervened with the instructional sequence designed considering the relevant theories, and the theory is restructured by planning with the help of the data obtained as a result of the intervention. In this design and reorganization process, different methods are used in cooperation with researchers, practitioners and participants, and the theory related to the learning process is combined with practice. Thus, a learning theory is created that explains the learning process of the field-specific learners and specifies the structures and patterns in this process (Cobb et al., 2003).

The design-based study takes place in three consecutive phases. The first phase is about construction of the learning theory. This theory is constructed by creating an HLT. It is a phase where the steps and tasks of the teaching sequence in which individuals' learning can take place are explained. The second phase is about implementation of this HLT, that is, the theory is tested by applying it. The final phase is about analysis of findings. In this phase, retrospective analysis takes place. The data are analyzed comprehensively and systematically to explain the reasons for certain inferences (Gravemeijer & Cobb, 2006).

The Hypothetical Learning Trajectory

HLT can be defined as "a hypothetical explanation of more sophisticated methods that evolve as students learn and explore an important area of knowledge or practice in an appropriate time frame" (Corcoran et al., 2009, p. 37). With hypothetical learning trajectories, teachers make assumptions about students' learning and test these assumptions during the instructional sequence. From this point of view, "… it is the teacher's prediction about the way that learning can progress … this is hypothetical because the actual learning trajectory is unknown and characterizes an expected trend" (Simon, 1995, p. 135). The fact that these cycles are not resistant to change makes it possible to make necessary changes in the teaching and learning process. In addition, considering the process of structuring knowledge in the constructivist approach, these loops can be considered as a cognitive tool that improves mental processes and mathematical learning actions (Clements & Sarama, 2004).

Hypothetical learning trajectories are created by considering the relationships between teacher knowledge and student learning. These trajectories have three basic components: learning goals, learning activities and hypothetical learning processes (Simon, 1995). In the scope of this study, HLT used in practice is summarized in **Table 1**.

Research Design

This study was performed by an exploratory sequential mixed method research design in order to examine the effect of the teaching sequence carried out using HLT on the development of PMTs' TPACK, with a holistic and analytical perspective in detail. In this design, qualitative and quantitative parts are carried out sequentially. Quantitative data are collected in order to test the accuracy of the qualitative data and results obtained after the completion of the analysis of the qualitative data or to provide evidence for these findings. Finally, the interpretation of the data obtained through qualitative and quantitative means is carried out not sequentially, but combining them (Creswell, 2012).

Table 1. Hypothetical learning trajectory

Stage	Learning goals	Learning activities	Hypothetical learning processes	Duration
1	Using technology in mathematics education & knowing Web 2.0 tools	Use of technology in mathematics education Introduction of Web 2.0 tools	Learn the use of related technology as a tool in mathematics Being familiar with Web 2.0 tools	1 week
2	Designing a learning environment Prepare a lesson plan	Planning a lesson Examining components of the lesson plan & developing a lesson plan	Learn stages of planning a lesson Examine & discuss the curriculum Examine sample lesson plans	1 week
3	Website & e-portfolio creation tool (content management systems)	Weebly (https://www.weebly.com)	Create a social learning platform Design a basic website	1 week
4	Collaborative learning tool (digital dashboard)	Padlet (https://padlet.com) Easelly (https://www.easel.ly) ThingLink (https://www.thinglink.com)	Prepare infographic Increase sharing & interactive interaction	3 weeks
5	Test preparation tools	Google Form (https://www.google.com/forms) TestHazırla.net (https://onlinetestmaker.net/) Mentimeter (https://www.mentimeter.com)	Learn & administrate the tools that can be used in the measurement & evaluation process	1 week
6	Interactive presentation/ animation tools	Powtoon (https://www.powtoon.com)	Prepare animations	2 weeks
7	Concept map & poster tools	Bubbl.Us (https://bubbl.us) Easelly	Identify & relate basic concepts & terms Highlight & present key concepts & terms visually	1 week
8	Puzzle & flashcard tools QR code tools	Crossword labs (https://crosswordlabs.com) QR stuff (https://www.qrstuff.com)	Prepare activities & materials to consolidate what has been learned	1 week
9	Augmented reality tool	Eyejack (https://creator.eyejackapp.com)	Design interactive clipboards	2 weeks
10	Product	Learning packages	Prepare a five-lesson learning package Make discussions & provide feedbacks	1 week

Study Group

The study group was formed by using convenience sampling strategy as one of the purposive sampling methods. Since this study was carried out within the scope of the "Computer supported mathematics teaching" elective course in elementary mathematics education undergraduate program, the study group was consisted of 63 female and 45 male in total 108 PMTs who voluntarily enrolled for this elective course.

The Intervention and Data Collection Processes

During the fourteen weeks of the course, PMTs were provided with distance education, as a result of COVID-19 pandemic measures, according to HLT that was prepared considering their professional development, and opportunities for learning and practice were provided. HLT has been prepared by considering the aims of the elementary mathematics education undergraduate program, instructional technologies, mathematics education, and the literature on the use of technology in mathematics education. HLT was administered to PMTs during this course on https://mergen.btk.gov.tr/ learning management systems used through distance learning periods for COVID-19 pandemic measures, along with Google Meet and Zoom platforms.

Throughout this course, first of all, information about the preparation of a lesson plan and design of learning environment packages were taught. With this information, they were asked to prepare lesson plan and learning packages. Then, opportunities for using Web 2.0 tools and various practices of experiencing these tools were provided to PMTs. Then, the advantages of using computers and the internet in lessons, and some features of Web 2.0 technologies were explained. After introducing and practicing Web 2.0 tools, which were given at **Table 1**, the participants were asked to prepare various learning environments by using these technologies. In this study, the PMTs prepared learning packages related to some objectives chosen from the middle school mathematics curriculum, before and after the course. These learning packages included lesson plans and descriptions about the learning environments.

During the intervention and data collection processes, the researchers held meetings to discuss the intervention process and the tasks carried out in the course every week, and in these meetings, if necessary some adjustments were made to HLT. In addition, at the end of the intervention, interview sessions were conducted with 10 randomly selected PMTs. These interview sessions with each of the participants lasted approximately 30 minutes. Therefore, the data of this study were collected through learning packages, which were designed by pre-service teachers before and after the intervention process and interview sessions held with some randomly selected participants.

Data Analysis

The data of the study were analyzed in order to evaluate the prepared learning trajectory. The data consisted of the learning packages prepared by PMTs and interview logs. Initially, the data including lesson plans were analyzed by adapting the TPACK assessment rubric developed by Akyuz (2018) to Web 2.0 tools by the researchers. This rubric is a performance evaluation rubric for evaluating lesson plans in the learning packages. The rubric includes three items for each dimension of the TPACK. Therefore, this rubric consists of 21 items in total. Scoring of each item ranged from one point (does not show the feature specified in the item) to maximum five points (strongly reflecting the feature indicated in the item). The coefficient of Cronbach's alpha of the adapted form of TPACK assessment rubric was also calculated as 0.90 as satisfactory value for reliability of total rubric. Moreover, the Cronbach's alpha values for dimensions were calculated as satisfactory reliability measures ranging from 0.85 to 0.90.

PMTs designed the learning packages including lesson plans before and after treatment. The lesson plans prepared before the treatment performed based on Web 2.0 tools were analyzed by scoring using the adapted form of TPACK as pre-study scores. Moreover, the lesson plans prepared after participating in the treatment were analyzed and scored by using the adapted form of TPACK as post-study scores. The quantitative data obtained from scoring learning packages by using the adapted form of TPACK performance rubric were analyzed using paired sample *t*-test since the following assumptions of the parametric tests were met. Gravetter and Wallnau (2013) explain the assumptions of this test, as follows:

(a) the measurements in each application should be independent, and

(b) the differences in the related measures between the applications should be normally distributed.

On the other hand, the qualitative data composed from learning packages, video recordings of lectures and interview logs were analyzed using descriptive analysis technique. In the qualitative data analysis process, initially, descriptive analysis using qualitative data was carried out through a diversity of researchers. The themes used in the descriptive analysis consisted of the types of knowledge in the TPACK model. Then, qualitative data obtained through interviews were also analyzed using the content analysis technique. In all of these analysis of the qualitative data, direct citation technique and researcher triangulation were used to ensure trustworthiness. In detail, the analysis of qualitative data was carried out by two researchers independently of each other. Then, the analysis was carried out by creating common codes and themes with the discussion of the researchers. In this analysis, *affective context*, *cognitive context*, and *flexibility* themes were merged and the data were inspected and reported in terms of these themes.

FINDINGS

Quantitative Findings

In this study, quantitative data were gathered through PMTs' lesson plans. In the scope of this study, PMTs prepared two lesson plans before and after the course about Web 2.0 tools. These lesson plans were evaluated with a performance assessment rubric in terms of evidence regarding dimensions of TPACK model for usage of Web 2.0 tools. Therefore, each PMT was scored for the accounted TPACK level in lesson plans. According to findings, first of all, scores of PMTs for their TPACK levels represented on lesson plans and learning packages prepared before and after the course about Web 2.0 tools were represented in **Figure 1**.

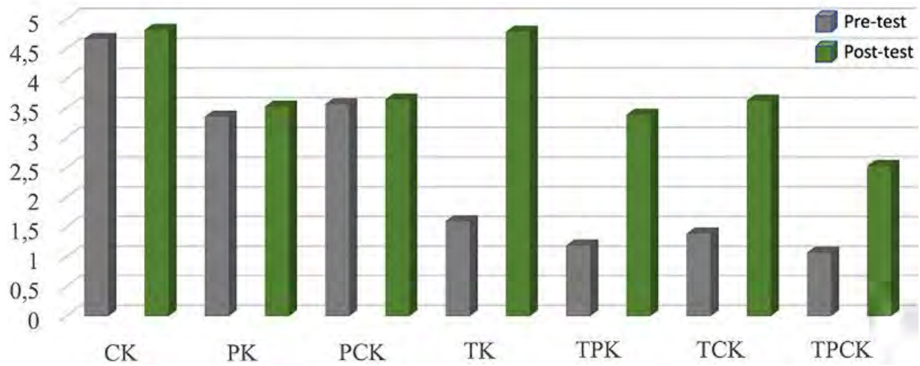


Figure 1. TPACK rubric average scores for Web 2.0 tools (Source: Authors' own elaboration)

Table 2. t-test results regarding TPACK pre- and post-study scores

Knowledge type	Time	n	M	SD	df	t	p
Content knowledge	Before course	108	4.67	0.40	107	4.96	.000
	After course	108	4.82	0.29			
Pedagogical knowledge	Before course	108	3.36	0.33	107	5.72	.000
	After course	108	3.53	0.33			
Pedagogical content knowledge	Before course	108	3.57	0.34	107	2.64	.009
	After course	108	3.65	0.25			
Technological knowledge	Before course	108	1.60	0.32	107	97.58	.000
	After course	108	4.79	0.24			
Technological pedagogical knowledge	Before course	108	1.19	0.25	107	64.58	.000
	After course	108	3.39	0.35			
Technological content knowledge	Before course	108	1.39	0.35	107	60.05	.000
	After course	108	3.63	0.34			
Technological pedagogical content Knowledge	Before course	108	1.07	0.15	107	34.21	.000
	After course	108	2.53	0.42			

As seen in **Figure 1**, it was observed that PMTS' scores for each dimension of the TPACK, in terms of each type of knowledge accounted to prepare lesson plans, increased throughout the study. This increase was observed more clearly in the dimensions of TK, TCK, TPK, and TPACK. In order to investigate whether these increases were statistically significant independent sample t-tests were conducted. For all dimensions of TPACK, results of these analyses were presented in **Table 2**.

According to results in **Table 2**, there were statistically significant differences in PMTS' the scores for all domains of TPACK acquired before and after the course. In detail, firstly, it was observed that there was a significant increase in the scores of the participants from the rubric regarding utilized CK levels in their lesson plans after the training on Web 2.0 tools ($t(107)=4.96$, $p<.00$). While the average score of the participants in the rubric's CK category was M=4.67 before the training, after the training, their average score increased to M=4.82 points. This finding showed that the training provided had a positive effect on the participants' reflecting their CK in the learning packages, which they designed using Web 2.0 tools. In terms of PMTs' scores for PK, a significant difference in the scores of the participants' before and after the training for designing lesson plans with Web 2.0 tools ($t(107)=5.72$, $p<.00$). While the average score of the participants in the PK category of the rubric was M=3.36 before the training, it increased to M=3.53 points after the training. This finding showed that the training provided had a positive effect on the participants' reflecting their PK in the learning packages they designed using Web 2.0 tools. Moreover, statistically significant difference between the PMTs' scores acquired before and after training in the dimension of PCK for their lessons plans was also observed ($t(107)=2.64$, $p<.00$). While the average score of the participants in the PCK category of the rubric was M=3.57 for their lesson plans designed before the training, it changed to M=3.65 after the training. This finding shows that the training provided has a positive effect on the participants' reflecting their PCK in the learning packages they designed using Web 2.0 tools.

In terms of TK, there was a significant difference between PMTs' scores on the rubric for their lesson plans designed before and after the course ($t(107)=97.58$, $p<.00$). This difference pointed out an increase for PMTs' TK and while the average score of the participants was M=1.60 before the training, it increased to M=4.79

after the study. This finding showed that the training provided improved the participants' knowledge of Web 2.0 tools, which belonged to a kind of technological tool group. Similarly, there was also a significant difference between PMTs' TPK scores on the rubric for their lesson plans designed before and after the course (t(107)=64.58, p<.00). Before the course, the average score of the participants in the TPK category of the rubric was M=1.19, but it was changed to M=3.39 after the study. This finding showed that the training provided had a positive effect on the participants' knowledge of Web 2.0 tools and integrating this knowledge with their PK as well as reflecting them on the learning packages. In addition to this result, in terms of TCK, there was a significant difference between PMTs' scores on the rubric for their lesson plans designed before and after the course (t(107)=60.05, p<.00). In detail, while the average score of the participants in the TCK category of the rubric was M = 1.39 before the training, it increased to M=3.63 after the study. This finding showed that this training had a positive effect on the participants' knowledge of Web 2.0 tools and integrating this knowledge with the knowledge about the content, which was focused and reflecting it on the learning packages.

Finally, the results showed that there was a significant difference between PMTs' general TPACK scores on the rubric for their lesson plans designed before and after the study (t(107)=34.21, p<.00). This result signified that while the average score of the participants in the TPACK category of the rubric was M=1.07 before the training, it changed to M=2.53 after the training completed. The findings state that the training provided had a positive effect on the participants' integrating their knowledge of Web 2.0 tools, with PK and CK, and reflecting this integrated knowledge into learning packages in a harmony.

Qualitative Findings

In this study, the use of Web 2.0 tools on lesson plans prepared by the participants were examined by considering the TPACK model and the types of knowledge it contains, before and after the training. The PMTs prepared websites using the Weebly tool to present their lesson plans. In these websites, the PMTs used some Web 2.0 tools to support their lessons, such as Geogebra, Powtoon, Easelly, Bubbl.us, Thinglink.

Findings related to the lesson plans prepared before the training

In general, the lesson plans, prepared before the training, of 30 participants prepared the lesson without using technology-related elements. Apart from this, it was observed that other participants generally used TK, TCK, TPK, and TPACK at a very low level in their lesson plans (see **Figure 1**). In terms of types of technological tools used on these plans, the PMTs generally benefited from the videos, visuals, and games in order to attract the attention of the students and inform them of the goal at the beginning of the lessons or to summarize the lesson at the end of the lessons. However, it was observed that the integration of these tools with pedagogical elements and the further enrichment of the mathematical content had not been successfully carried out while designing lesson plans. In fact, it was observed that some students were familiar with GeoGebra and added a simple activity to the lesson plans with this tool. However, it was seen that they tended to use this tool to visualize mathematical content as static rather than to enhance understanding of students with dynamic contents. For example, a student used GeoGebra for the topic of prisms. In the lesson plan itself, he only showed a prism and a net of this prism in GeoGebra. However, he did not focus on carrying out the construction stages of prisms on Geogebra with dynamic contents by asking questions or giving directions to the students and supporting them with discussions. For this reason, it was observed that even if these pre-service teachers used GeoGebra as a tool for teaching, they could not accomplish this successfully, in other words, they could not successfully integrate this software with pedagogical and CK. For this reason, it has been observed that the student used the limited features of the software and could not fully integrate it with the mathematical contents by considering basic features of this technological tool, and used TK and TCK, as well as TPK and TPACKs at a very low level.

Findings related to the lesson plans prepared after the training

The lesson plans, which the PMTs prepared after the training, involved Powtoon, Easelly, Bubbl.us, and Thinglink activities. They created websites, which were called learning packages and included their lesson plans and supporting activities prepared via Web 2.0 tools. The use of Web 2.0 tools were investigated, and it seemed that the PMTs used Web 2.0 tools to evaluate the students' prior understanding about previous related concepts and to introduce key points of learning subjects, to present learning subjects in more catchy

Figure 2. A poster about equations designed (Source: Produced by one of the participants by using Easelly, reprinted with permission of the participant)

way for students, to summarize the learning subjects and to evaluate students' learning about the subjects. Some of the examples about integration of these tools on the lesson plans were summarized.

Some of the participants used Web 2.0 tools for the purpose of evaluating and summarizing what was learned before. For example, a PMT created a poster using Easelly for the purpose of summarizing the subject (see **Figure 2**). This student's integration of this tool in the learning package was evaluated as sufficient in terms of TK, CK, and TCK because this student's scores for these dimensions on the rubric were sufficient as having the calculated mean value more than four. In other words, in these types of knowledge, he received an average score from the scale. This value was accepted as sufficient in order to use related knowledge in designing a lesson using Web 2.0 tools. This value was determined by analyzing the participants' lesson plans and discussions made by the researchers about the necessary level of knowledge types. The researcher made discussions about the least knowledge necessitated to design lessons. In the poster, he could effectively represent CK by explaining mathematical content appropriately, TK by using the properties and commands of the tool and TCK by using the tool appropriately and accurately to explain the mathematical content.

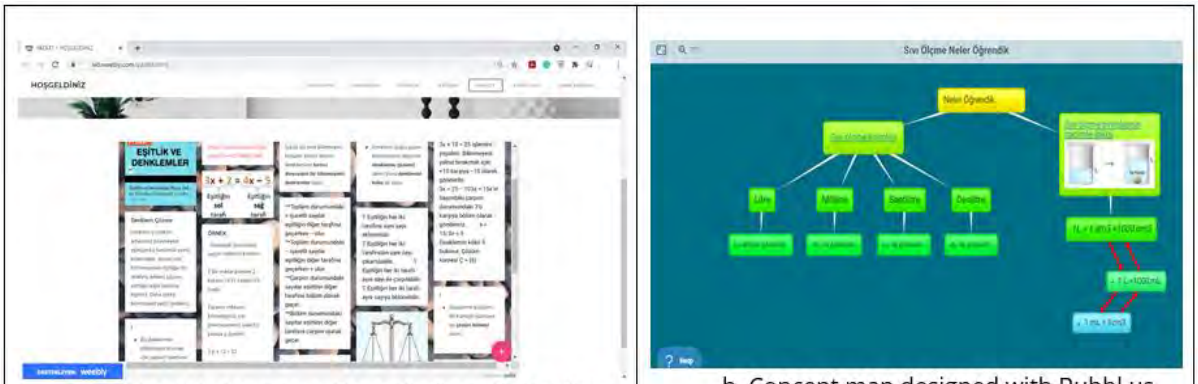
Secondly, some of the PMTs used Web 2.0 tools to introduce the key points of the learning subjects. For example, a student prepared an animation by using Powtoon for teaching fractions as a part of the learning package to introduce key points about fractions (see **Figure 3**). In this animation, the definition of fraction, its representation and unit fractions were explained. In this learning package, this animation was used as a tool in teaching the subject of fractions with the question-answer technique. It was seen that the student was able to combine TK with CK and PK on this lesson package by integrating this animation with his lesson plan. Therefore, his progress on the lesson plan showed that he was also able to use TPACK by integrating these three types of knowledge. This student got four points for each type of knowledge from the scale in the scoring of these knowledge types since his examples were not in real-life situations.

Figure 3. Sample scenes from an animation for fractions (Bir kesir nasıl gösterilir: How to represent a fraction; Basit kesirler: Proper fractions; Pay: Numerator; Kesir çizgisi: Fraction bar/vinculum; & Payda: Denominator) (Source: Produced by one of the participants by using Powtoon, reprinted with permission of the participant)

Figure 4. A page about Pythagorean theorem (Source: Designed by one of the participants using Thinglink, reprinted with permission of the participant)

In the learning packages, it was seen that some of the PMTS used Web 2.0 tools to present learning subjects in a more attractive way. For example, a PMT integrated the history of mathematics effectively with mathematical content in the learning packages so that she prepared a learning package in which learning subjects were taught in a funny way. Here, a sample page was created using the Thinglink tool, where the content of the Pythagorean Theorem, its history and its relationship with other lessons were conveyed in a visual and funny way (see **Figure 4**). When the blue annotation figures on the left side of **Figure 4** are clicked on, the explanation pages appear. This PMT's creation of these tools in the learning package was evaluated as sufficient level in terms of TK, CK, and TCK. In these types of knowledge, she received the score of five points for the items on the scale.

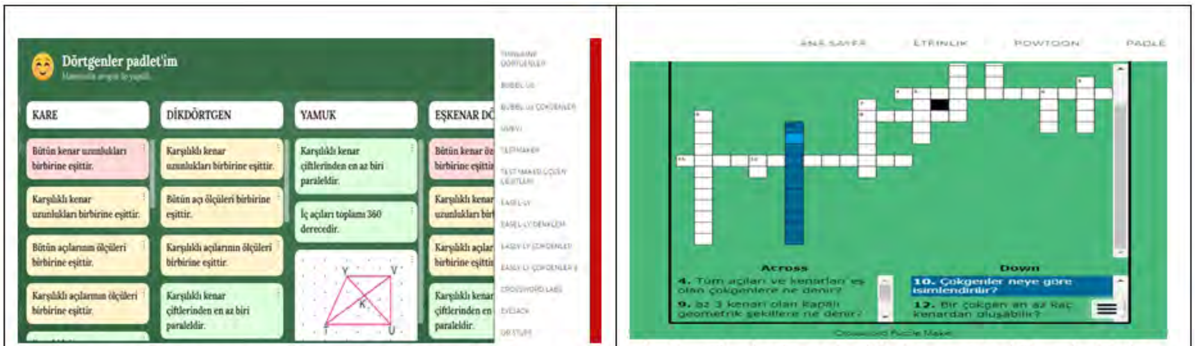
Some of the PMTs used Web 2.0 tools as a way to summarize lessons. For example, a PMT also used a Web 2.0 tool to summarize the learning subjects in her lesson plan and learning package. She created a board using Padlet (see **Figure 5a**) and transferred some key concepts and examples about the subjects from her lesson plan to this board. However, the fact that since this Padlet board just included concepts, definition and written examples and it was not supported with pedagogically rich content, it showed that PK of the PMT could not be effectively integrated with CK and TK. Therefore, the PMT was at an intermediate level in terms of TPK, PCK and TPACK knowledge types. For this reason, this student got the average score from the scale in these types of knowledge by acquiring three points from the items of these knowledge types.



a. A board about equations design with Padlet

b. Concept map designed with Bubbl.us

Figure 5. Board and concept map examples (Source: Designed by the participants by using Padlet, reprinted with permission of the participants)



a. A concept map designed with Padlet for quadrilaterals

b. Puzzle designed with Crossword Puzzle Maker for quadrilaterals

Figure 6. Screenshot examples (Source: Designed by one of the the participants, reprinted with permission of the participant)

Another PMT also used Web 2.0 tools to summarize what was learned in the lesson as well as to evaluate students' learning, using Bubbl.us, one of the Web 2.0 tools, to evaluate student learning. Here, a concept map as one of the most effective pedagogical methods in consolidating and summarizing what was learned about measuring in participant fluids, was created (see **Figure 5b**). In this learning package, the pre-service teacher presented this concept map formation with pedagogical question-answer and discussion techniques, and in terms of CK. This pre-service teacher presented all kinds of knowledge effectively in the learning package.

Another PMT used Padlet in order to summarize the concept of quadrilaterals including square, rectangle, trapezoid and equilateral parallelogram in **Figure 6a**. This participant also prepared the puzzle in order to make the lesson more attractive and funnier with the aim of summarizing the concept by using Crossword Puzzle Maker in **Figure 6b**.

Findings from the Interview Sessions

In this study, interview sessions were held after the training. 10 randomly selected participants were interviewed via Google meet. In these interview sessions, the PMTs were asked to explain their experiences. The experiences of the PMTs were analyzed and three themes emerged from this analysis as *affective context*, *cognitive context*, and *flexibility*.

First of all, the theme of affective context was formed from the PMTs' explanations about their experiences with Web 2.0 tools about attracting students' attention, making lessons full of fun, and increasing students' motivation. Some of the explanations of the participants about their experiences are, as follows:

"These tools were funny even for me while I was practicing, …" (making lessons full of fun).

> "They even attracted my interest and increased my motivation" (attracting students' attention, increasing students' motivation).
>
> "Combining the visuals, animations and sounds are very effective. In particular, the questions that could worry the students or even the questions asked to assess their end-of-course learning can become funnier and relieve the fears of the students …" (making lessons full of fun, increasing students' motivation).

Secondly, the codes in the cognitive context theme can be exemplified as supporting conceptual understanding, evaluating learning, and teaching, and making abstract contents concrete. The explanations of some PMTs as an example of this theme are, as follows:

> "… mathematics subjects are abstract and difficult to learn for students. Here, the features of Web 2.0 tools make it easy for students to make these topics more concrete in a funny way. It makes the connection of subjects with real life more effective" (making abstract contents concrete).
>
> "I think I can enhance understanding with the digital story I prepared using the Powtoon tool in my lesson plan" (supporting conceptual understanding).
>
> "… I also think that I can perform the evaluation much more effectively. I think that assessment questions asked with this tool will support active participation of students in assessment" (evaluating learning and teaching).

Lastly, PMTs' explanations about their experiences included in the flexibility theme were formed from the codes of flexibility in time, place, strategy, and creativity. Some examples for explanations of PMTs coded regarding these codes are, as follows:

> "In this course, we learned how to assign homework, upload lecture notes, prepare games and videos, and create a website where we can share them with students. Thanks to these [Web 2.0] tools, students could access the lesson content here whenever and wherever they want" (flexibility in time, flexibility in place).
>
> "Their [students'] learning could be supported with the content here. These tools can even be taught to students, which can improve their creativity and support them to produce new things and share the products they create with their friends on these websites. They can discuss them" (flexibility in strategy and creativity).

In summary, PMTs in this study stated that they gained effective and different experiences and so the training about Web 2.0 tools was beneficial for them. According to the interview sessions, PMTs believed that these Web 2.0 tools could also be beneficial providing different opportunities for their future students. Their explanations about experiences on Web 2.0 tools throughout this study revealed when they become teachers in the future, the training in this study enables them to gain knowledge and skills that will support their conceptions about *affective context, cognitive context*, and *flexibility*. In addition, this study showed that when enough experiences with Web 2.0 tools were provided to PMTs, they can design a learning environment supported with these tools by combining their knowledge about technology, pedagogy, and content.

DISCUSSIONS AND CONCLUSIONS

In the study, an alternative educational content that could be used in lessons related to instructional technologies in undergraduate programs training mathematics teachers had been prepared and progress of the PMTs were investigated. In the teaching environment, PMTs gained experience during fourteen weeks, where they could develop various knowledge and skills related to the use of various Web 2.0 tools and their integration into mathematics lessons. Within the scope of this design-based research, the design and implementation of a teaching sequence enriched with educational content prepared using Web 2.0 tools, and the evaluation of its effect on the participants were carried out. From this point of view, it was planned to present a rich educational content that had been tested and made necessary arrangements at the end of the study. How Web 2.0 tools and the instructional sequence guided based on the designed HLT supported the development of pre-service teachers was also revealed with qualitative and quantitative data in the findings section of the study.

Mathematics lessons aims to support students to develop their mathematical skills, including mathematical communication, reasoning, and proof, and making mathematical associations, in such a way that students can acquire mathematical competencies including understanding, application, calculation, reasoning and interest (Kilpatrick & Swafford, 2002). Therefore, mathematics teachers should effectively realize the knowledge and skills that can meet these expectations during their undergraduate education. For this reason, in this study, it was aimed to realize the knowledge and experiences of PMTs that could meet these expectations during the instructional sequence including activities supported by Web 2.0 tools. It is of great importance to acquire this knowledge and some experience with technological tools because the presence or use of technological tools in a course may not mean that the course holds an effective integration of technology in mathematics. In addition, the research in the related literature have emphasized the benefits of introducing technological tools in content and pedagogical context in undergraduate courses in order to gain the necessary knowledge and skills for the integration of technology into lessons (Caliskan et al., 2019; Karaca & Aktas, 2019; Thohir et al., 2022). Therefore, this study focused on the development of PMTs' TPACK, specifically through using Web 2.0 tools.

In the study, the lesson plans prepared by the PMTs before the study were examined in terms of the knowledge types included in the TPACK model. Based on the analysis of lesson plans, low levels of TPACK were observed, especially in terms of the knowledge types related to technology knowledge. The related previous research have claiming that PMTs could not be at a sufficient level in technology-related knowledge if they did not acquire experiences with technological tools during their undergraduate education (Bilici & Guler, 2016; Mouza et al., 2014; Pamuk et al., 2012; Rakes et al., 2022) confirm this finding. On the other hand, after the implementation of HLT throughout an undergraduate course, it was seen that the PMTs' knowledge levels in terms of all types of TPACK (CK, PK, PCK, TK, TCK, TPK, and TPACK) were improved. Based on the PMTs' development of TPACK, it was observed that HLT appeared to be beneficial for PMTs since this HLT offered them effective opportunities for gaining experiences with different Web 2.0 tools. Previous studies in the literature also encouraged the observed development by indicating that the types of technology-related knowledge and its transformation into skills can develop with the experience gained through the training provided and the opportunities offered (Cetin, 2017; Karatas et al., 2016; Meagher et al., 2011; So & Kim, 2009; Teo et al., 2019; Yigit-Koyunkaya, 2017). Moreover, there exist research specifically related to Web 2.0 tools stating that this development, which can be supported by experience in technology-related knowledge, is valid while working on Web 2.0 tools with experience (Teo et al., 2019).

In the literature, some researchers stated that in the previous research, teachers and pre-service teachers could not use some kinds of Web 2.0 tools, even if they were familiar with them or recognize the tools, due to lack of knowledge, but this issue could be eliminated with an appropriate training, which includes both theoretical knowledge and experiences (Yetik et al., 2020). This issue, which was stated in previous studies, was also observed in this study. It has been observed that the PMTs had low level of technologically related knowledge types in their lesson plans, which they prepared before the study. While they engaged in various kinds of Web 2.0 tools and used them in these plans, they started to include and use some Web 2.0 tools effectively in the lesson plans, which they prepared at the end of the study. Hence, it could be stated that pre-service teachers learned how to use these tools in mathematics education rather than how to use Web 2.0 tools in general purposes in the undergraduate course, which was guided by HLT. Therefore, in this study, Web 2.0 tools were used specifically for mathematics education in order to support the development of PMTs' TPACK in line with the recommendations of Guerrero (2010) and Voogt et al. (2012). Thus, the technological content knowledge, TPK and TPACKs of PMTs were also encouraged as TK with the help of HLT formed in this study.

The interview sessions held with PMTs revealed their views about using technology in the learning environment and the effects of instructional sequence on PMTs' TPACK levels. They started to realize some opportunities and importance of using technological tools in a learning environment for their professional development and supporting student learning. Therefore, it can be concluded that the PMTs started to consider these possible opportunities while they were designing and developing a learning environment enriched by Web 2.0 tools. Therefore, at the end of the study they were able to design learning environments and prepare lesson plans and learning packages by effectively integrating the TK, CK, and PK they had as suggested by Agyei and Voogt (2012).

Suggestions

Teachers' knowledge and skills related to technological tools have an effect on their capacity of integrating and using technological tools in the learning phase. Some researchers have clarified that if PMTs have various experiences with technological tools in their undergraduate courses, they will better integrate technology in their lessons through their professions and so they will present their future students different opportunities by using technological tools in their learning environment. Kafyulilo et al. (2015) also emphasized the importance and the effect of integrating these different types of knowledge to form TPACK on teaching in their study. Therefore, it is of great importance that PMTs develop their skills and experiences about these types of knowledge in an integrated way by forming TPACK, rather than teaching the TK, CK and PK, separately. In this way, they can acquire the necessary knowledge that they can use when they become teachers in the future and transform them into skills. These knowledge and skills can be effectively acquired through teaching practices or microteaching by PMTs. They can also more effectively shape their perspectives based on their profession. Moreover, further research including the implementation of the designed lessons plans using Web 2.0 tools can be performed.

In the current study, it was aimed to design, implement, and test HLT that allows PMTs to experience certain Web 2.0 tools and to prepare lesson plans for teaching based on these experiences to express their knowledge into practice. Since HLT designed in the current study supported the PMTs' development of TPACK knowledge, new trajectories can be prepared, or this trajectory can be revised by using other types of Web 2.0 tools. This HLT focused on specifically improving TPACK of PMTs via Web 2.0 tools, future studies can also be created in relation to other technological software and tools in a similar way. Therefore, by creating hypothetical learning trajectories in which different innovative technology tools are discussed, rich course contents for PMTs could be prepared to contribute their professional development on TPACK. Future studies can be conducted for primary and secondary school students who continue formal education with a revised HLT for their level and the effects of these tools on students' mathematics learning can be investigated as well as contribution of these tools on affective and cognitive domains.

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