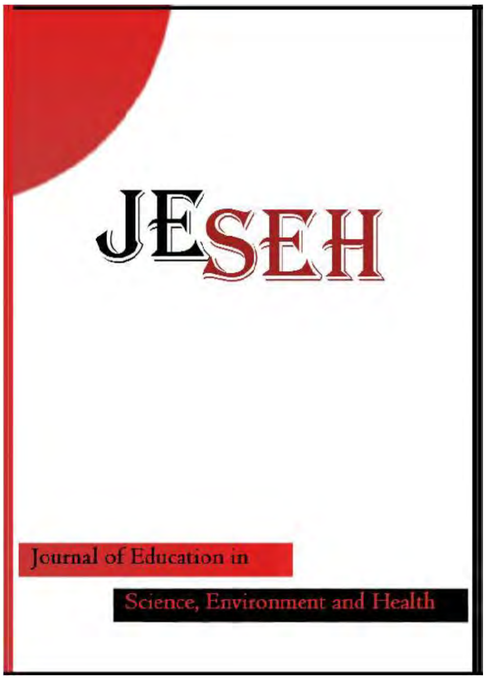

ISSN: 2149-214X

Journal of Education in Science, Environment and Health

www.jeseh.net

Preservice Science Teachers' TPACK Development in a Technology-Enhanced Science Teaching Method Course

Tezcan Kartal, Irem Dilek
Kırşehir Ahi Evran University

To cite this article:

Kartal, T. & Dilek, I. (2021). Preservice science teachers' TPACK development in a technology-enhanced science teaching method course. *Journal of Education in Science, Environment and Health (JESEH), 7*(4), 339-353. https://doi.org/10.21891/jeseh.994458

Journal of Education in Science, Environment and Health
Volume 7, Issue 4, 2021
https://doi.org/10.21891/jeseh.994458

Preservice Science Teachers' TPACK Development in a Technology-Enhanced Science Teaching Method Course

Tezcan Kartal, Irem Dilek

Article Info

Article History

Published:
01 October 2021

Received:
08 May 2021

Accepted:
27 October 2021

Keywords
TPACK,
Science education,
Science teaching method course

Abstract

This study investigated preservice elementary science teachers' TPACK development throughout a science teaching method course. The pretest-posttest control group was used in the study. At the end of the study, a self-reported TPACK measure was administered to the experimental (n=26) and control (n=23) groups. The experimental group learned about instructional technologies that can be used in science teaching; prepared technology-based science activities, shared these activities with their peers; planned and taught a mini technology-based lesson, evaluated the lesson, and replanned and retaught the lessons. The results showed that the experimental group had positive gains about how to integrate technologies into science teaching. Participants in the experimental group comprehended that teaching science with technology requires more than technical knowledge and skills and that it is essential to realize the interactions between science, technology, and pedagogy. Besides, the experimental group's TPACK significantly differed from the control group. The implications and suggestions were given based on the results.

Introduction

Technology redesigns the learning environment (McLeod & Richardson, 2013) and only improve learning when used appropriately (ISTE, 2016). Science classrooms are natural environments where technology use will occur, as science depends on technology. Technology should be used to perform actions that are complex or impossible without technology. Technology can help embody science subjects and attract students' attention to science (Rehmat & Bailey, 2014). The widespread use of technology in the schools made it essential to guide teachers about the correct use of technology and effective technology integration (Chen et al., 2009). Teachers play a central role in deciding how to incorporate technologies to facilitate and support student learning (Christensen, 2002). Therefore, teachers are expected to prepare students with 21st-century skills, including using new technologies (Kartal, 2017; Kartal & Tasdemir, 2021; Lambert & Gong, 2010; Niess, 2008), and be knowledgeable and skilled in using various ICT-based approaches in their teaching practice (Inan & Lowther, 2010).

Addressing the importance of technology integration in preservice teacher (PST) education, the International Society for Technology in Education has established ISTE standards for teachers and students (ISTE, 2016; 2017). These standards have become an essential component of the learning process. Given the need for developing technology knowledge of PSTs, teacher preparation programs (TPPs) have begun to incorporate the curriculum focusing on teaching PSTs to integrate technology into their classroom (Lambert & Gong, 2010; Niess, 2005). While stand-alone educational technology courses can help increase PSTs' confidence in using technology (Kleiner et al., 2007), they are sometimes insufficient to encourage PSTs to integrate technology effectively into their teaching practices (Wachira & Keengwe, 2011). Therefore, researchers suggest that technology education should be integrated into the teacher education program to encourage more effective technology integration (Niess, 2005; Tondeur et al., 2012). Niess (2005) suggested that TPPs adopt a multidimensional approach that focuses on developing PSTs' competencies in teaching a specific subject area (mathematics/science) with technology each semester. Educators agree that technology can no longer be considered a separate body of knowledge isolated from pedagogical and content knowledge. Mishra and Koehler (2006) introduced TPACK (technological pedagogical content knowledge) as the technology integrated PCK to define the teacher knowledge needed for effective technology integration.

It may be challenging for researchers to determine which approaches may be effective in helping PSTs develop their technological knowledge and skills for future teaching practices (Goktas et al., 2008). Teachers need more opportunities to teach science as an integrated set of knowledge and understand how technologies help learn science (Bransford et al., 2000; Kartal, 2017). Therefore, developing TPACK within science learning and teaching will support teachers in designing and conducting experimental research for their students (Metz, 2008). PSTs need to have a solid understanding of content areas to integrate technology effectively into their learning and teaching experiences (Mishra & Koehler, 2009) and have productive approaches to use technology in conjunction with practical strategies in the context of pedagogical approaches (Harris & Hofer, 2011). Thus, the conceptual framework of Technological Pedagogical Content Knowledge (TPACK) developed by Mishra and Koehler (2006) is widely used to guide technology integration. In this study, the development of preservice science teachers' knowledge required for technology integration during a method lesson was investigated using the TPACK framework.

Theoretical Framework: TPACK

Shulman (1986) pointed out the appropriate selection and use of technologies to represent the content. Using appropriate technologies, if needed, was a part of the curriculum knowledge. Over the years, researchers have tried to combine technology with Shulman's pedagogical content knowledge (PCK). Many researchers emphasized that technological knowledge should be included in Shulman's PCK notion, and technology should be considered an essential component of PCK (Kartal & Afacan, 2017; Kartal & Çınar, 2018; Koehler & Mishra, 2005; Margerum-Leys & Marx, 2002; Mishra & Koehler, 2006; Niess, 2005). Niess (2005) emphasized the importance of helping PSTs develop a comprehensive understanding of what it means to teach with technology. Niess described this knowledge base as "a technology PCK (TPCK)." Mishra and Koehler (2006) developed the TPACK framework more comprehensively and systematically. They created a visual, conceptual framework showing the teacher knowledge required for technology integration (Figure 1).

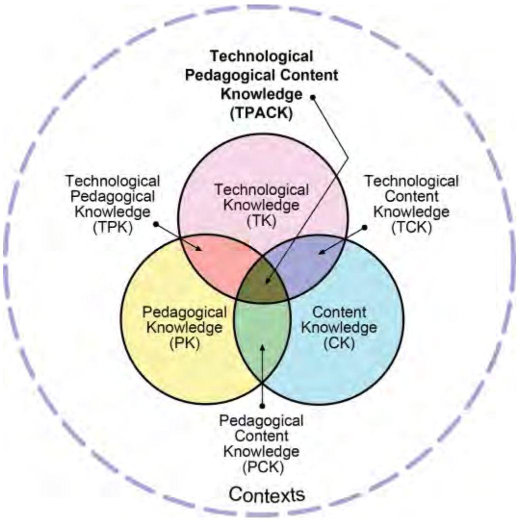

Figure 1. The TPACK framework illustration is adapted from http://tpack.org

It is challenging to assess the relationship between having knowledge of technology and integrating technology (Niess, 2005). Technology should not be considered a separate knowledge or skill to be learned later. TPACK is a valuable theoretical framework for thinking about what teachers should know to integrate technology (Harris & Hofer, 2011; Mishra & Koehler, 2006) and how they can develop this knowledge (Koehler & Mishra, 2008). TPACK helps us understand the difficulties teachers face in integrating technology into the curriculum (Mishra & Koehler, 2006).

The TPACK framework provides a perspective to develop better techniques for exploring and explaining how technology-related professional knowledge occurs in practice (Koehler & Mishra, 2009; Mishra & Koehler, 2006). TPACK framework includes technology knowledge (TK), content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK). The emphasis on integrated knowledge areas (TCK, TPK, PCK, and TPACK) is also essential for defining this framework. TPACK is a synthesized form of information that emerges from TK, PK, and CK interactions. Mishra and Koehler's (2006, 2009) TPACK framework requires knowing and using various new technologies that enable the teaching, representation, and facilitation of knowledge in a particular subject area (Chai et al., 2013; Kartal, 2020; Kartal & Afacan, 2017; Koehler & Mishra, 2009).

Content knowledge is the knowledge about a particular subject matter (e.g., science concepts) (Shulman, 1986). Since the nature of knowledge differs from subject matter to subject matter (e.g., science and mathematics), it is critical for teachers to deeply know the disciplines they teach (Mishra & Koehler, 2006; Shulman, 1986) and to develop CK (Koehler & Mishra, 2008). Teachers should know the content they will teach and how knowledge differs for the various content areas.

Pedagogical knowledge is the teacher's knowledge in creating and facilitating effective teaching and learning environments for students (Koehler & Mishra, 2008). Three types of PK are defined: general pedagogical knowledge, personal pedagogical knowledge, and context-specific pedagogical knowledge (Morine-Dershimer & Kent, 1999). General PK includes knowledge of teaching strategies, teaching models, classroom management, classroom organization, and classroom communication and discourse (Chai et al., 2013; Harris, Mishra, & Koehler, 2009; Hilton, 2016; Mishra & Koehler, 2006; Padmavathi, 2017). Personal PK is concerned with practical experiences and personal beliefs and perceptions (Morine-Dershimer & Kent, 1999). Context-specific pedagogical knowledge is formed by combining both general and personal PK.

Technological knowledge involves the knowledge and skills required to use and master various technological tools (Chai et al., 2013; Harris et al., 2009; Hilton, 2016; Mishra & Koehler, 2006). TK is considered a type of knowledge produced and adapted through new and changing technologies (Harris et al., 2009; Koehler & Mishra, 2008). Teachers who are fluent in information technologies can develop appropriate ways to accomplish a particular task with technology and constantly adapt to technological changes (Bransford et al., 2000; Koehler & Mishra, 2008).

Pedagogical content knowledge is the interaction between pedagogy and content knowledge (Mishra & Koehler, 2006). PCK is a distinctive characteristic between educators and content professionals in specific content areas (Shulman, 1987). For example, scientists may have rich CK but may not have the pedagogical content knowledge necessary to become effective science educators. PCK helps develop instructional applications in content (Koehler & Mishra, 2008; Padmavathi, 2017). For example, a science teacher with strong pedagogical content knowledge guides students to think about how the buoyant force of liquids occurs and the factors that affect this force while knowing how students develop their ideas and what misconceptions they may have.

The component that needs the most scaffolding within the framework of TPACK is *technological content knowledge* (Koehler & Mishra, 2008). This form of knowledge requires knowing and understanding how technology can affect and be used in a subject area (Chai et al., 2013; Harris et al., 2009; Hilton, 2016; Mishra & Koehler, 2006; Padmavathi, 2017). For example, a science teacher needs technological content knowledge to determine which technologies can be used for tasks such as explaining how to measure gravity, comparing the differences between the earth's gravity and the moon's gravity, and observing the absence of gravity.

Technological pedagogical knowledge includes knowing which technologies are compatible with teaching and learning strategies in particular grade levels (Harris et al., 2009) and which technologies best contribute to specific educational contexts (Chai et al., 2013; Mishra & Koehler, 2006). For example, in teaching the buoyancy and effects of fluids, a science teacher needs technological pedagogical knowledge to recognize the pros and cons of using diagrams, animations, or simulations to help students understand the concept.

Technological pedagogical content knowledge is a framework for understanding and defining the knowledge, and skills teachers need for effective pedagogical practice in a technology-supported learning environment (Padmavathi, 2017). PSTs are expected to understand how students can utilize technology to improve their knowledge of the subject matter (Cox & Graham, 2009). Practical experiences with technology should be specific to content areas (Niess, 2005; Schmidt et al., 2009). For example, to help students understand how gravity works, a science teacher with TPACK can use a gravity simulator to make students explore properties that affect gravity (mass and distance) and study the effects of gravity on objects. With the representations of the gravity simulator, the teacher asks students to observe and explain the relationship between the force of gravity and the mass of related objects.

TPACK and TPACK Development in Science Education

PSTs should have the necessary knowledge and skills to integrate technologies into the classroom and use them in a pedagogically appropriate way (McCrory, 2008; Niess et al., 2010). US Department of Education (2017) emphasized that technology-supported professional learning experiences should increase teachers' digital literacy and create learning activities that improve learning, teaching, evaluation, and teaching practices. PSTs' perceptions of teaching and learning stem from their personal experiences about teaching (Richardson-Kemp & Yan, 2003).

Given the importance of developing technology knowledge in teachers, TPPs focused on preparing teachers to use technology in classrooms. Most TPPs typically offer a stand-alone educational technology course to meet specified technology requirements (Lambert & Gong, 2010). These educational technology courses may increase PSTs' confidence in using technology, but they may not be effective in encouraging PSTs to integrate technology effectively into teaching practices (Wachira & Keengwe, 2011). In TPPs, PSTs can develop TPACK by taking educational technology courses, context-specific teaching methods courses, or practicums and engaging with the TPACK knowledge domains during these courses (Hofer & Grandgenett, 2012). Harris and Hofer (2011) stated that after attending the TPACK-focused professional development program, teachers' awareness of curriculum-based learning activities increased with technology integration. Teachers' TPK evolved, their choices of technology-based learning activities were more structured diverse, and their lesson plans became student-centered. They also reported that teachers had raised their quality standards for technology integration, and their decisions for the use of educational technology have become more purposeful.

The educational technology course is essential for prospective teachers' professional development and provides a foundation for technology integration. The developed skills in educational technology courses can be transferred to the teaching method courses. Therefore, it seems necessary to examine how these skills can be developed in TPPs (Kartal & Çınar, 2018; Kleiner et al., 2007). Schmidt et al. (2009) examined how PSTs' TPACK changed after taking an instructional technology course. PSTs had statistically significant gains in all seven TPACK knowledge domains after completing a required technology course, with a large increase in the fields of TK, TCK, and TPACK. Chai, Koh, and Tsai (2010) found significant differences in the TPACK knowledge domains between pretest and post-test results of PSTs who attended an educational technology course.

Maeng, Mulvey, Smetana, and Bell (2013) investigated the development of preservice science teachers' TPACK through technology-enhanced inquiry education. The results showed that the participants perceived the value of the technology and utilized the appropriate technologies to facilitate the inquiry experiences. Lehtinen et al. (2016) investigated the effect of using simulations in science teaching on preservice science teachers' TPACK development. There were statistically significant differences between pre and post-tests in CK, PK, and TPACK knowledge domains. Preservice science teachers' TK was associated with their views on the usefulness of simulation and their tendency to integrate simulations in teaching. Similarly, Habowski and Mouza (2014) stated that a content-specific technology integration course could develop PSTs' understanding to combine technology with science and pedagogy. In addition, the content-centric nature of the lesson encouraged PSTs to think about TCK more often than TPK.

PSTs need to develop strategic thinking that includes planning, organizing, and criticizing specific content, student needs, and specific classroom situations. Method courses provide a natural environment to build the knowledge, skills, and tendencies defined in TPACK (Kartal & Çınar, 2018; Mouza et al., 2017; Niess, 2008). In the study conducted by Mouza and colleagues (2014), PSTs attended the educational technology course, method course, and field experience via an integrated approach. At the end of the study, TPACK increased significantly. In addition, it was found that PSTs' TK, TPK, and TPACK improved in their field experiences. More experiences in teaching technology-related information in classrooms will encourage PSTs' PCK and TPACK development, which will lead to more confidence and more positive attitudes in teaching (Zhan et al., 2013).

Alayyar et al. (2012) used the TPACK framework to prepare preservice science teachers for ICT integration. The results reported an increase in participants' TK, TPK), attitudes towards ICT as a tool for instruction and productivity, and enjoyment of ICT. Kaplon-Schilis and Lyublinskaya (2015) investigated changes in preservice special teachers' TK, PK, CK, and TPACK in a technology-based science and mathematics instruction course. PSTs showed a significant difference in TPACK but did not significantly change PK, TK, and CK during the course. Participants made various progress in their TPACK development, and the average scores of all TPACK components showed that participants progressed from acceptance level to adaptation level.

Kafyulilo et al. (2015) concluded that participating in professional development programs that include designing, teaching, assessment, and redesigning may effectively develop PSTs' knowledge and skills integrate technology into science and mathematics instruction. In the research conducted by Jang (2010), it is addressed that (i) science teachers used interactive boards as a teaching tool to share their CK and express students' understanding, (ii) interactive boards improved the representation repertoire and teaching strategies of science teachers who had difficulties in the traditional classroom, and (iii) the proposed model to integrate interactive boards and peer coaching could improve science teachers' TPACK.

TPACK is a practical conceptual framework for thinking about teachers' knowledge to integrate technology into teaching. Researchers examined PSTs' TPACK development in professional development programs (Chai et al., 2013; Graham et al., 2009; Harris & Hofer, 2011; Kafyulilo et al., 2015), instructional technology (IT) courses (Agyei & Keengwe, 2014; Habowski & Mouza, 2014; Maeng et al., 2013; Mouza et al., 2014, 2017) and teaching method courses (Lehtinen et al., 2016; Maeng et al., 2013; Mouza et al., 2014, 2017; Buss et al., 2018). Using the TPACK framework may be helpful when designing professional experiences for PSTs (Schmidt et al., 2009). The science teaching methods course is a fruitful context for PSTs' TPACK development (Polly et al., 2010). However, more research still needs to investigate preservice science teachers' TPACK development in different contexts (Maeng et al., 2013). This study examined the effect of a science teaching method course that included experiences of learning and teaching science with technology on preservice elementary science teachers' TPACK development within the context of a pretest-posttest control group design. The research questions that guided the study are:

(1) Are there any differences in the pretest scores of the experimental (the science teaching method course that included technology-supported learning and teaching experiences) and the control (the science teaching method course that does not include technology-supported learning and teaching experiences) groups?
(2) Are there any differences between the pretest and post-test scores of the experimental group?
(3) How did the relationships between the experimental participants' TPACK (central component) and other knowledge domains change through the science teaching method course?
(4) Are there any differences between the pretest and post-test scores of the control group?
(5) Are there any differences in the post-test scores of the experimental and the control groups?

Method

Research Design

This study investigated the effect of a science teaching method course enhanced with the experiences related to learning and teaching science with technology on preservice science teachers' TPACK. A pretest-posttest control group design was used (e.g., Kafyulilo et al., 2015; Lehtinen et al., 2016). Two cohorts of the method course were assigned randomly as experimental and control groups. Data were collected simultaneously in both groups (Fraenkel et al., 2012). Table 1 demonstrates the research design.

Table 1. The pretest-posttest control group research design

Groups		Pretest	Treatment	Posttest
Control Group	R_1	O		O
Experimental Group	R_2	O	X	O

R_1, R_2: Random assignment
O: TPACK self-assessment scale (Dependent variable)
X: Technology-enhanced science teaching method course

Participants

Considering the ethical issues, we started the research process by obtaining the necessary official permissions from the university administration where the research was conducted. In addition, further information about the research was given to the preservice teachers who will participate in the research, and voluntariness was necessary to participate in the study. Participants were informed that the data obtained during the research would be used only for the purpose and scope of the research. The research was carried out in the natural setting of the participants. The data obtained during the research were not used to create clues about the participants (name, gender, age, etc.).

Senior preservice science teachers who enrolled in the two cohorts of science teaching method courses in a university located in Central Anatolia were asked to participate voluntarily in the study. The TPP offers a four-year undergraduate education for elementary science teacher education. Until the final year (6 semesters), PSTs took many different CK, PK, pedagogical content knowledge, and TK courses. A TPACK self-assessment scale was administered as a pretest to 54 PSTs at the beginning of the course. To ensure the equivalence of the experimental and control groups' pretest scores in the central component, TPACK, we excluded two PSTs from the experimental group and three PSTs from the control group from the data analysis. The numbers of the females and males in control and experimental groups were given in Table 2.

Table 2. Females and males in the experimental and control groups

Groups	Female	Male	Total
Experimental Group	19	7	26
Control Group	17	6	23
Total	36	13	49

Finally, 49 PSTs ($N_{experimental}$=26, $N_{control}$= 23) participated in the study. Nineteen of the experimental group PSTs and 17 of the control group PSTs were female. The participants ranged in age from 21 to 24 (M = 22.4).

Research Context

In the first four weeks of the course, the experimental group participants were introduced to instructional technologies specific and not specific to science. The instructor (first author) addressed how to integrate various technologies (such as animation, video, digital stories, etc.) into science and the difficulties that can be faced in teaching science with technology, and how to overcome these difficulties. Experimental group PSTs learned about interactive puzzles (eclipse crossword), interactive presentation tools (Prezi), probeware, concept map software (inspiration), PhET (physics education technology), crocodile physics, and interactive physics programs (Kartal, 2017). Then they were grouped into three to four. These groups developed activities related to integrating these technological tools when teaching science and shared their activities with their peers within the course. Teaching how to use various instructional tools in science teaching and allowing the PSTs to develop activities with these tools took four weeks.

Then, PSTs were asked to design a technology-supported mini science lesson (15 minutes) individually and teach this mini-lesson to their peers (microteaching). The lectures of each PST were videotaped. The whole PSTs watched these videos in the class. Then the lessons were evaluated by themselves (self-assessment), the course instructor (expert assessment), and peers (peer assessment). The instructor aimed to help PSTs reflect on their lessons based on the assessments. After the assessment, PSTs had the opportunity to redesign and reteach their lessons. The reteaching try-outs were also video-recorded, but they were not re-evaluated in the classroom environment. The limited time allocated for the course was effective in not making the second assessment. This limited time can be considered as a limitation depending on the number of PSTs. With the technology-supported microteaching, PSTs actively experienced the teaching process. Considering the assessments, they had the opportunity to reflect on how and why various technologies were integrated into science teaching. The PSTs experienced planning a lesson and activity and adapting innovative teaching methods and strategies in this section of the course.

PSTs in the control group did not receive training related to instructional technologies. They were asked to plan and teach a mini-science lesson (15 minutes). The lectures in this group were not video-recorded and were not evaluated. For this reason, the second lecture (reteaching) did not occur in this cohort.

Table 3. Sample items, number of items, and Cronbach' alpha for each TPACK knowledge domain

Construct	Exemplary Item	Number of Items	Cronbach's α
PK	I think I can determine teaching methods according to students' levels.	15	.965
TK	I think I do not have trouble using technology.	11	.932
CK	I think I know conceptions, rules, and generalizations in my content area.	8	.924
TCK	I think I can use technology to help abstract concepts be learned.	5	.963
TPK	I think I know how technology affects teaching and learning.	10	.936
PCK	I think I am familiar with students' misconceptions about a specific topic.	11	.944
TPACK	I think I can decide which technologies positively affect teaching and learning.	7	.925

Data Collection Tool

It is common to use questionnaires in examining TPACK development (Schmidt et al., 2009). In this context, TPACK Self-Assessment Scale, TPACK-SAS, was used to investigate the TPACK development of preservice science teachers. TPACK-SAS was developed by Kartal et al. (2016) and included seven factors and 67 items. The scale items are 7-point Likert ranging from "strongly agree" to "strongly disagree" to increase the reliability of the measurement, as suggested by Thorndike (2005). The researchers used the thinking aloud strategy with two preservice science teachers who were not participants to increase the validity of the scale items. Sample items, number of items, and Cronbach's alpha values for each subdimension of the scale are given in Table 3.

Data Analysis

Before analyzing data from the TPACK-SAS, it was examined whether the data had a normal distribution. Kolmogorov-Smirnov normality test was performed, and the Skewness-Kurtosis values were calculated. Kolmogorov-Smirnov value was not statistically significant (p>.05), and skewness-kurtosis values were calculated as .516 and -.407, respectively. If the Kolmogorov-Smirnov test results are not significant for data with a sample size of more than 50, it shows that the data has a normal distribution. According to Tabachnick and Fidel (2019), kurtosis-skewness values should be between +1.5 and -1.5 for the normal distribution. According to the results of the normality tests and skewness-kurtosis values, it can be said that the data set has a normal distribution.

SPSS was used in the analysis of the data in this study. Before analyzing the data, the data were examined for missing data. The t-tests were used for dependent and independent groups to compare the mean scores within and between groups. The effect size was calculated to determine the level of the difference between groups or variables. Effect size describes the magnitude of the observed effects regardless of the possible misleading impact of the sample size. The effect sizes for the TPACK-SAS results were calculated using Cohen's d. The effect sizes of .2, .5, and .8 were interpreted as a *small*, *medium*, and *large* effect sizes, respectively (Cohen, 1988). Pearson's correlation analysis was also used to examine the relationships between the central TPACK and other knowledge domains.

Results

Results Related to Pretest

The equivalence of the experimental and control groups was examined by comparing preservice science teachers' pretest scores in the central TPACK component. The results are given in Table 4.

Table 4. T-test results regarding the pretest mean scores of the experimental and control groups

Scale	Administration	Group	N	M	Sd	t	p
TPACK (Central Component)	Presurvey	Experimental Group	26	5.385	.650	.019	.985
		Control Group	23	5.389	.660		

Table 4 demonstrates that the control group (M=5.389) had higher mean scores than the experimental group (M=5.385) in the pretest. However, the difference between mean scores ($M_{control}$-$M_{experimental}$=.004) is not statistically significant (t=.019, p>.05). It is possible to say that there is no difference between the experimental and control groups regarding the central TPACK component.

Results Related to Pretest and Post-test of The Experimental Group

The experimental group's mean scores in TPACK knowledge domains were compared, and the results were given in Table 5. Preservice science teachers showed statistically significant gains in their PK (t=1.969, p<.05; d=.547), CK (t=2.723, p<.05, d=.770), TPK (t=2.556, p<.05, d=.565) and TPACK (t=4.071, p<.05; d=1.151). The largest gain was in TPACK. The experiences of learning and teaching science with technology may have improved participants' CK, PK, knowledge of pedagogy due to selected technology, and knowledge of pedagogy, technology, and content. The gains in PK, CK, and TPK had medium effect sizes. Additionally, participants rated themselves higher in the post-test than the pretest in TK, TPK, and PCK, but these gains were not statistically significant.

Table 5. t-test results regarding the pretest and post-test mean scores of the experimental group

Knowledge Domains	Group	Administration	N	M	Sd	t	p	Cohen's d
PK	Experimental Group	Pretest	26	5.548	.521	1.969	.045*	.547
		Post Test	26	5.851	.584			
TK	Experimental Group	Pretest	26	4.874	1.151	.553	.583	-
		Post Test	26	5.038	.985			
CK	Experimental Group	Pretest	26	4.447	1.263	2.723	.009*	.770
		Post Test	26	5.208	.661			
TCK	Experimental Group	Pretest	26	5.553	.833	1.399	.168	-
		Post Test	26	5.838	.617			
TPK	Experimental Group	Pretest	26	5.400	.748	2.556	.014*	.565
		Post Test	26	5.859	.528			
PCK	Experimental Group	Pretest	26	5.807	.793	.278	.782	-
		Post Test	26	5.867	.749			
TPACK	Experimental Group	Pretest	26	5.461	.598	4.071	.000*	1.151
		Post Test	26	6.082	.497			

The change in relationships between the central TPACK component and other knowledge domains throughout the study was given in Figure 2.

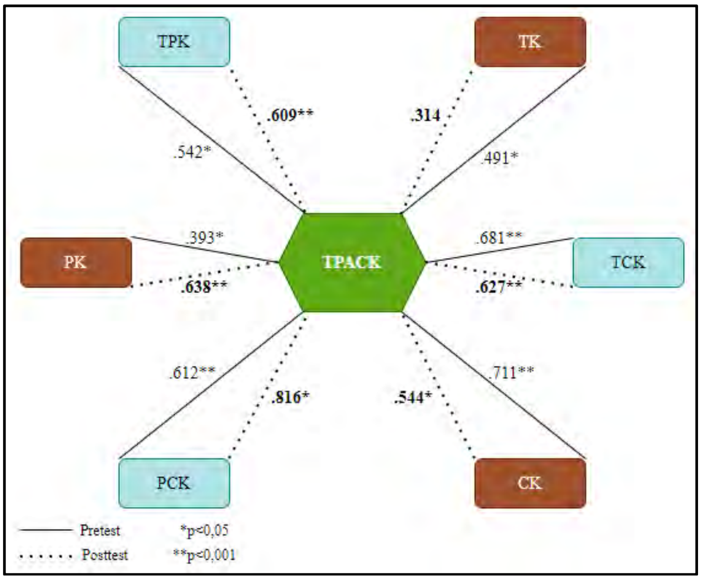

Figure 2. Correlation coefficients between the central TPACK component and other knowledge domains at the beginning and the end of the course

PSTs' TPACK was significantly correlated with their PK (r=.393, p<.05), TK (r=.491, p<.05), CK (r=.711, p<.001), TPK (r=.542, p<.05), TCK (r=.681, p<.001), and PCK (r=.612, p<.001) at the beginning of the course; and with their PK (r=.638, p<.001), CK (r=.544, p<.05), TPK (r=.609, p<.001), TCK (r=.627, p<.001), and PCK (r=.816, p<.001) at the end of the course. The post-test results demonstrated that TPACK was not significantly correlated with TK (r=.314, p>.05). The correlations between the central TPACK component and PK, TPK, and PCK increased significantly at the end of the course. The significant gains in PK may lead to strengthen the correlation between these constructs. In addition, the correlation between content-specific and technology-specific PK and TPACK increased. The development of these knowledge domains (PK, TPK, and PCK) are expected to contribute to the development of the TPACK. However, it is seen that there is a strong correlation, although the correlation coefficient between TPACK and CK and TCK decreased.

Results Related to Pretest and Post-test of The Control Group

The control group's mean scores in TPACK knowledge domains were compared, and the results were given in Table 6.

Table 6. t-test results regarding the pretest and post-test mean scores of the control group

Knowledge Domains	Group	Administration	N	M	Sd	t	p	Cohen's d
PK	Control	Pretest	23	5.736	.764	-.862	.393	-
	Group	Post Test	23	5.573	.481			
TK	Control	Pretest	23	4.924	1.159	1.376	.176	-
	Group	Post Test	23	5.339	.865			
CK	Control	Pretest	23	4.552	1.053	1.603	.116	-
	Group	Post Test	23	5.005	.968			
TCK	Control	Pretest	23	5.652	.615	1.436	.158	-
	Group	Post Test	23	5.904	.574			
TPK	Control	Pretest	23	5487	.809	2.579	.013	.760
	Group	Post Test	23	6.000	.505			
PCK	Control	Pretest	23	5.691	.920	1.175	.246	-
	Group	Post Test	23	5.968	.655			
TPACK	Control	Pretest	23	5.559	.853	.488	.628	-
	Group	Post Test	23	5.670	.692			

PSTs in the control group had higher scores in the post-test than in the pretest in knowledge domains except for PK. For PK, participants' pretest scores were higher than their post-test scores. The difference between mean scores of TPK is statistically significant (t=2.579, p<.05; d=.760) with a *medium* effect size. These results may imply that the control group perceived themselves as more knowledgeable in technology-related PK at the end of the course.

Results Related to Post-survey

The independent t-test results regarding post-test mean scores of the experimental and control groups were given in Table 7.

Table 7. t-test results regarding the post-test mean scores of the experimental and control groups

Knowledge Domains	Group	Administration	N	M	Sd	t	p	Cohen's d
PK	Post Test	Experimental Group	26	5.851	.584	1.175	.046*	.519
		Control Group	23	5.573	.481			
TK	Post Test	Experimental Group	26	5.038	.985	1.131	.264	-
		Control Group	23	5.339	.865			
CK	Post Test	Experimental Group	26	5.208	.661	.864	.392	-
		Control Group	23	5.005	.968			
TCK	Post Test	Experimental Group	26	5.838	.617	.385	.702	-
		Control Group	23	5.904	.574			
TPK	Post Test	Experimental Group	26	5.859	.528	.947	.349	-
		Control Group	23	6.000	.505			
PCK	Post Test	Experimental Group	26	5.867	.749	.500	.619	-
		Control Group	23	5.968	.655			
TPACK	Post Test	Experimental Group	26	6.082	.497	2.412	.020*	.683
		Control Group	23	5.670	.692			

Table 7 demonstrates that the experimental group's PK (t=1.175, p<.05, d=.519) and TPACK (t=2.412, p<.05; d=.683) significantly differed from the control group in the post-test. These significant differences had *medium* effect sizes. Technology-based science learning and teaching experiences positively affected preservice science teachers' PK and TPACK.

Results and Discussion

This study investigated the effect of a technology-enhanced science teaching method course on preservice elementary science teachers' TPACK, using a pretest-posttest control group design. A self-reported measure, TPACK-SAS, was used at the beginning and end of the course to allow PSTs to rate their competencies in teaching with technology. The experimental group included 26 participants, and the control group had 23. The pretest and post-test mean scores of the experimental group are given in Figure 3. The experimental group had significantly positive gains in PK, CK, TPK, and TPACK. The largest effect of the method course was in the central TPACK component.

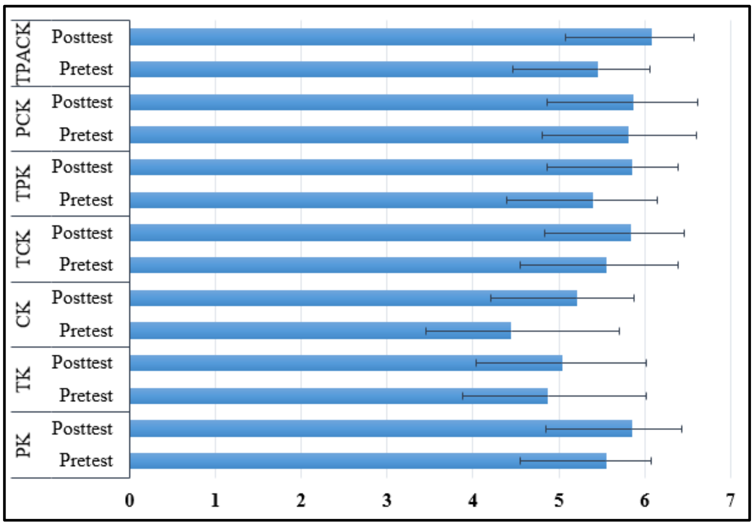

Figure 3. The pre-and-posttest mean scores of the experimental group

PSTs are expected to acquire PK related to teaching strategies, teaching models, classroom management, organization, and communication and discourse until their final year. The teaching experiences in the course may allow PSTs to transfer their theoretical knowledge into practice and lead to an improvement in their PK. This result is similar to the results of many studies (Chai et al., 2010, 2013; Lehtinen et al., 2016; Morine-Dershimer & Kent, 1999; Pamuk, 2012). Morine-Dershimer and Kent (1999) stated that as PSTs gained experience designing lessons and teaching practices, they would become more comfortable in pedagogy.

The positive gains in the CK of the experimental group may be because of PSTs' experiences related to planning and teaching a mini science lesson. PSTs may have tried to explain and exemplify the concepts and principles related to the science concepts they would teach. This may have contributed to the development of their CK. In the study conducted by Lehtinen et al. (2016), science teachers integrated interactive whiteboard resources such as e-books, animation, and the internet into teaching and learning. They had positive changes in their CK.

The method course that included learning and teaching science with technology positively affected the experimental group's TPK. This result may imply that the course promoted PSTs' understanding of the interactions and associations between technology and pedagogy. Figg and Jaipal (2009) stated that teachers need TPK to integrate technology successfully. They expressed that TPK plays a crucial role in planning and implementing successfully, and the lack of this integrated knowledge may negatively affect teaching practices. The literature reported similar (Alayyar et al., 2012; Jaipal & Figg, 2010; Koh & Divaharan, 2011) and different (Mouza et al., 2014; Pamuk, 2012; Polly et al., 2010) results. The introduction of technologies and the discussions about integrating instructional technologies into science teaching may have guided PSTs to consider how technology changes specific pedagogies and vice versa. Additionally, planning a science lesson two times may have improved their TPK.

The most significant gain occurred in the central TPACK component. It is possible to say that the method course, including technology-enhanced science learning and teaching activities, is an effective means of improving PSTs' TPACK. The course helped PSTs perceive themselves as increasing the knowledge and competencies needed for effective technology integration. The developing TPACK has been seen in many research (Agyei & Voogt, 2012; Chien, Chang, Yeh, & Chang, 2012; Koh & Divaharan, 2011; Zhan et al., 2013). Teaching experience effectively improves PCK and TPACK (Agyei & Voogt, 2012; Zhan et al., 2013). However, it is worth noting that the PCK of participants did not improve significantly, even though they experienced planning and teaching two times. This may be because the participants rated themselves most competent in PCK in the pretest. Similarly, Kafyulilo and colleagues (2015) reported that their professional development program did not improve participants' PCK significantly since the participants were relatively high in PCK at the start of the program.

The absence of significant improvements in PSTs' TK and TCK needs to be considered since the first four weeks of the course included introducing instructional technologies and allowing participants to prepare technology-enhanced science activities. It may be challenging to develop TCK (Chai et al., 2013). It is needed more than introducing specific technologies; PSTs need to explore and use more technologies specific to science. Additionally, PSTs may not have perceived the instructional technologies as tools for developing their technological competencies. The duration allocated to using these technologies (four weeks) may be insufficient to develop TK and TCK.

The study revealed the relationships between the central TPACK component and other knowledge domains at the beginning and end of the course. The results showed that the integrated knowledge domains (TPK, TCK, and PCK) were significantly correlated to the central TPACK component at the beginning and end of the course. The correlation coefficients between the integrated knowledge domains and the central TPACK component increased at the end of the study. These results may imply that the PSTs had an integrative view that assumed that teaching with technology requires a comprehensive understanding of relationships between technology, pedagogy, and content (Agyei & Keengwe, 2014; Koehler & Mishra 2009; Shin, Koehler, Mishra, Schmidt, Baran, & Thompson, 2009). The increase of the coefficients implied that the course supported PSTs' integrated TPACK understanding. Similar results include significant relationships between knowledge domains (Lin, Tsai, Chai, & Lee, 2013) and the strengthening relationships between TPACK and TCK, TPK, and PCK (Shin et al., 2009).

Additionally, TPACK was correlated significantly to TK at the beginning of the study but not correlated at the end of the study. PSTs perceived that having TK and skills is not the same as teaching science with technology. This result underpins the assertion that TK is not enough for effective technology integration (Koh & Divaharan, 2011; Mishra & Koehler, 2006). This result is promising as PSTs realized that teaching science with technology requires more than technical knowledge and skills.

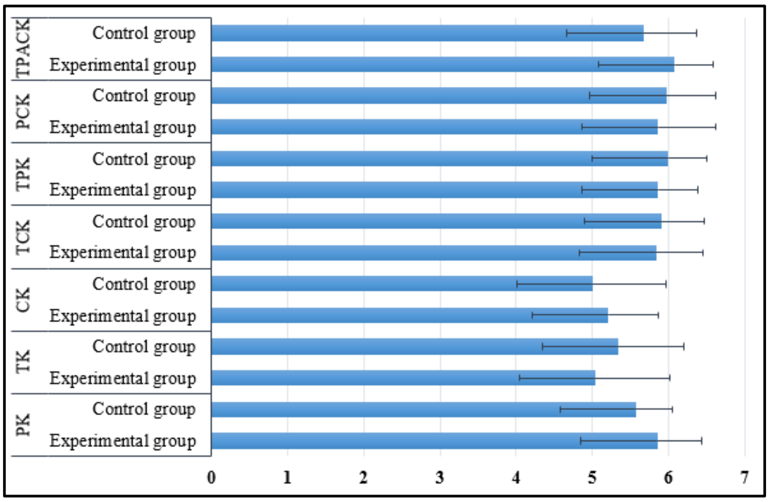

Figure 4. Mean scores of the experimental and control groups in the post-test

This research also compared the groups' mean scores at the end of the course (Figure 4). PSTs in the experimental group rated themselves as more competent than PSTs in the control group in PK and TPACK. The distinguishing characteristics of the intervention in the experimental group were introducing instructional technologies that can be used in science teaching, allowing PSTs to prepare science activities with these technologies, sharing their activities with peers, and engaging in the cycle of teaching-evaluating-reteaching. It is possible to say that incorporating these strategies into teaching method courses promotes preparing PSTs equipped with the knowledge they need to integrate technology effectively.

Recommendations

This study revealed that a science teaching method course incorporating experiences of learning and teaching science with technology developed participants' PK, CK, TPK, and TPACK, promoted PSTs' integrative view of TPACK, and guided PSTs to realize the interactive and dynamic relationships among technology, pedagogy, and science. However, there are some limitations. This study used a self-reported measure that may reveal crucial findings. It is worth expressing that these measures may not reflect participants' actual teaching practices (Jaipal & Figg, 2010). Further research may use various data collection tools (such as observation, interview, lesson plans, and artifacts) and self-reported measures to understand better how PSTs will teach science concepts with technology.

This study took one semester and was conducted in a science teaching method course. The duration allocated for introducing instructional technologies to teach science with technology seems insufficient in developing PSTs' TK and TCK. The longitudinal studies investigating TPACK development within science-specific technology courses, science teaching method courses, and student teaching may help researchers deepen their understanding of PSTs' TPACK development.

Scientific Ethics Declaration

The authors declare that the scientific, ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

References

Agyei, D. D., & Keengwe, J. (2014). Using technology pedagogical content knowledge development to enhance learning outcomes. *Education and Information Technologies*, *19*(1), 155-171.

Agyei, D., & Voogt, J. (2012). Preservice teachers' competencies for technology integration: Insights from a mathematics-specific instructional technology course. In P. Resta (Ed.), *Proceedings of SITE 2012-Society for Information Technology & Teacher Education International Conference* (pp. 1094–1099). Austin, Texas, USA: Association for the Advancement of Computing in Education (AACE).

Alayyar, G. M., Fisser, P., & Voogt, J. (2012). Developing technological pedagogical content knowledge in preservice science teachers: Support from blended learning. *Australasian journal of educational technology*, *28*(8), 1298-1316.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). Technology to Support Learning (Eds). *How people learn: Brain, mind, experience, and school* (Exp. Ed.). Washington, DC: National Academy Press.

Buss, R. R., Foulger, T. S., Wetzel, K., & Lindsey, L. (2018). Preparing teachers to integrate technology into K–12 instruction II: Examining the effects of technology-infused methods courses and student teaching. *Journal of Digital Learning in Teacher Education*, *34*(3), 134-150.

Chai, C. S., Koh, J. H. L., & Tsai, C. (2010). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). *Educational Technology & Society, 13*(4), 63-67.

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2013). A review of technological pedagogical content knowledge. *Journal of Educational Technology & Society*, *16*(2), 31-51.

Chen, F., Looi, C., & Chen, W. (2009). Integrating technology in the classroom: A visual conceptualization of teachers' knowledge, goals and beliefs. *Journal of Computer Assisted Learning*, *25*(5), 470-488.

Chien, Y. T., Chang, C. Y., Yeh, T. K. & Chang, K. E. (2012). Engaging preservice science teachers to act as active designers of technology integration: A MAGDAIRE framework. *Teaching and Teacher Education, 28*(4), 578-588.

Christensen, R. (2002). Effect of technology integration education on the attitudes of teachers and students. *Journal of Research on Technology in Education, 34* (4), 411-433.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd Ed.). Hillsdale, NJ: Erlbaum.

Cox, S., & Graham C. R. (2009). Diagramming TPACK in practice: using and elaborated model of the TPACK framework to analyze and depict teacher knowledge. *TechTrends, 53*(5), 60-69.

Figg, C., & Jaipal, K. (2009). Unpacking TPACK: TPK characteristics supporting successful implementation. In I. Gibson, R. Weber, K. McFerrin, R. Carlsen & D. Willis (Eds.), *Proceedings of SITE 2009--Society for Information Technology & Teacher Education International Conference* (pp. 4069-4073). Charleston, SC, USA: Association for the Advancement of Computing in Education (AACE). Retrieved from https://www.learntechlib.org/primary/p/31295/

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to Design and Evaluate Research in Education* (8th Ed.). McGraw–Hill Companies: New York, NY.

Goktas, Y., Yıldırım, Z., & Yıldırım, S. (2008). A review of ICT related courses in preservice teacher education programs. *Asia Pacific Education Review, 9*(2), 168-179.

Graham, C., Burgoyne, N., Cantrell, P., Smith, L., Clair, L., & Harris, R. (2009). TPACK development in science teaching: Measuring the TPACK confidence of in-service science teachers. *TechTrends, 53*(5), 70-79.

Habowski, T., & Mouza, C. (2014). Preservice teachers' development of technological pedagogical content knowledge (TPACK) in the context of a secondary science teacher education program. *Journal of Technology & Teacher Education, 22*(4), 471-495.

Harris, J. B., & Hofer, M. J. (2011). Technological pedagogical content knowledge (TPACK) in action: A descriptive study of secondary teachers' curriculum-based, technology-related instructional planning. *Journal of Research on Technology in Education, 43*(3), 211-229.

Harris, J. B., Mishra, P., & Koehler, M. (2009). Teachers' technological pedagogical content knowledge: Curriculum-based technology integration reframed. *Journal of Research on Technology in Education, 41*(4), 393-416.

Hilton, J. T. (2016). A case study of the application of SAMR and TPACK for reflection on technology integration into two social studies classrooms. *The Social Studies*, *107*(2), 68-73.

Hofer, M., & Grandgenett, N. (2012). TPACK development in teacher education: A longitudinal study of preservice teachers in a secondary MA Ed. program. *Journal of Research on Technology in Education*, *45*(1), 83-106.

Inan, F. A., & Lowther, D. (2010). Laptops in the K-12 classrooms: Exploring factors impacting instructional use. *Computers & Education*, *55*(3), 937–944.

International Society for Technology in Education [ISTE]. (2016). *National educational technology standards for students: Connecting curriculum and technology.* Eugene, OR: Author.

International Society for Technology in Education [ISTE]. (2017). *ISTE Standards for Educators: A guide for teachers and other professionals.* Retrieved from https://www.iste.org/standards/for-educators

Jaipal, K., & Figg, C. (2010). Unpacking the "Total PACKage": Emergent TPACK characteristics from a study of preservice teachers teaching with technology. *Journal of Technology and Teacher Education*, *18*(3), 415-441.

Jang, S. J. (2010). Integrating the interactive whiteboard and peer coaching to develop the TPACK of secondary science teachers. *Computers & Education*, *55*(4), 1744-1751.

Kafyulilo, A., Fisser, P., Pieters, J., & Voogt, J. (2015). ICT use in science and mathematics teacher education in Tanzania: Developing technological pedagogical content knowledge. *Australasian Journal of Educational Technology*, *31*(4), 381-399.

Kaplon-Schilis, A., & Lyublinskaya, I. (2015). Exploring changes in technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK) and TPACK of pre-service, special education teachers taking technology-based pedagogical course. In D. Rutledge & D. Slykhuis (Eds.), *Proceedings of SITE 2015-Society for Information Technology & Teacher Education International Conference* (pp. 3296-3303). Las Vegas, NV, United States: Association for the Advancement of Computing in Education (AACE). Retrieved from https://www.learntechlib.org/primary/p/150456/

Kartal, B. (2020). Teknoloji temelli öğrenme-öğretme yaklaşımı: Teknolojik pedagojik alan bilgisi. G. Ekici, (Ed.), *Etkinlik Örnekleriyle Güncel Öğrenme-Öğretme Yaklaşımları-IV* (s. 353-403). Ankara: Pegem Akademi.

Kartal, B., & Çınar, C. (2018). Examining preservice mathematics teachers' beliefs of TPACK during a method course and field experience. *Malaysian Online Journal of Educational Technology*, *6*(3), 11-37.

Kartal, B., & Taşdemir, A. (2021). Preservice teachers' attitudes towards STEM: Differences based on multiple variables and the relationship with academic achievement. *International Journal of Technology in Education (IJTE), 4*(2), 200-228.

Kartal, T. (2017). Fen Eğitiminde Teknoloji Entegrasyonu. M. P. Demirci Güler, (Ed.), *Fen Bilimleri Öğretimi: Yaklaşımlar ve Kazanımlar Doğrultusunda Uygulama Örnekleri* (s. 165-199). Ankara: Pegem Akademi.

Kartal, T., & Afacan, Ö. (2017). Examining Turkish pre-service science teachers' technological pedagogical content knowledge (TPACK) based on demographic variables. *Turkish Journal of Science Education, 14*(1), 1-22.

Kartal, T., Kartal, B., & Uluay, G. (2016). Technological pedagogical content knowledge self-assessment scale (TPACK-SAS) for preservice teachers: Development, validity and reliability. *International Journal of Eurasia Social Sciences*, *7*(23), 1-36.

Kleiner, B., Thomas, N., & Lewis, L. (2007). Educational Technology in Teacher Education Programs for Initial Licensure (NCES 2008–040). *National Center for Education Statistics, Institute of Education Sciences, US Department of Education.* Washington, DC.

Koehler, M. J., & Mishra, P. (2005). What happens when teachers design educational technology? The development of Technological Pedagogical Content Knowledge. *Journal of Educational Computing Research. 32*(2), 131-152.

Koehler, M., & Mishra, P. (2008). Introducing TPACK. In AACTE Committee on Innovation and Technology (Eds.). *Handbook of technological pedagogical content knowledge for educators* (pp. 3-29). New York, NY: Routledge.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)?. *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60-70.

Koh, J. H., & Divaharan, H. (2011). Developing preservice teachers' technology integration expertise through the TPACK-developing instructional model. *Journal of Educational Computing Research*, *44*(1), 35-58.

Lambert, J., & Gong, Y. (2010). 21st century paradigms for preservice teacher technology preparation. *Computers in the Schools*, *27*(1), 54-70.

Lehtinen, A., Nieminen, P., & Viiri, J. (2016). Preservice teachers' TPACK beliefs and attitudes toward simulations. *Contemporary Issues in Technology and Teacher Education*, *16*(2), 151-171.

Lin, T. C., Tsai, C. C., Chai, C. S., & Lee, M. H. (2013). Identifying science teachers' perceptions of technological pedagogical and content knowledge (TPACK). *Journal of Science Education and Technology*, *22*(3), 325-336.

Maeng, J. L., Mulvey, B. K., Smetana, L. K., & Bell, R. L. (2013). Preservice teachers' TPACK: Using technology to support inquiry instruction. *Journal of Science Education and Technology*, *22*(6), 838-857.

Margerum-Leys, J., & Marx, R. (2002). Teacher knowledge of educational technology: A study of student teacher/mentor teacher pairs. *Journal of Educational Computing Research*, *26*(4), 427-462.

McCrory, R. (2008). Science, technology, and teaching: The topic-specific challenges of TPCK in science. In M. C. Herring, M. J. Koehler, & P. Mishra (Eds). *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 193-206). AACTE Committee on Innovation and Technology. New York: Routledge for the American Association of Colleges for Teacher Education.

McLeod, S., & Richardson, J. (2013). Supporting effective technology integration and implementation. In M. Militello, & J. I. Friend (Eds.), *Principal 2.0: Technology and Educational Leadership* (pp. 249–272). Charlotte, NC: Information Age Publishing.

Metz, K. E. (2009). Elementary school teachers as "targets and agents of change": Teachers' learning in interaction with reform science curriculum. *Science Education, 93*(5), 915-954.

Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for integrating technology in teacher knowledge. *Teacher College Record, 108*(6), 1017-1054.

Mishra, P., & Koehler, M. (2009). Too cool for school? No way! Using the TPACK framework: You can have your hot tools and teach them, too. *Learning & Leading with Technology, 36*(7), 14-18.

Morine-Dershimer, G., & Kent, T. (1999). The Complex Nature and Sources of Teachers' Pedagogical Knowledge. In J. Gess-Newsome, & N. G. Lederman (Eds). *Examining Pedagogical Content Knowledge: The Construct and Its Implications for Science Education.* New York: Kluwer Academic Publishers.

Mouza, C., Karchmer-Klein, R., Nandakumar, R., Ozden, S. Y., & Hu, L. (2014). Investigating the impact of an integrated approach to the development of preservice teachers' technological pedagogical content knowledge (TPACK). *Computers & Education*, *71*, 206-221.

Mouza, C., Nandakumar, R., Yilmaz Ozden, S., & Karchmer-Klein, R. (2017). A longitudinal examination of preservice teachers' technological pedagogical content knowledge in the context of undergraduate teacher education. *Action in Teacher Education, 39*(2), 153-171.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509-523.

Niess, M. L. (2008). Guiding preservice teachers in developing TPCK. In M. C. Herring, M. J. Koehler, & P. Mishra (Eds). *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 223-250). AACTE Committee on Innovation and Technology. New York: Routledge for the American Association of Colleges for Teacher Education.

Niess, M. L., Van Zee, E. H., & Gillow-Wiles, H. (2010). Knowledge growth in teaching mathematics/science with spreadsheets: Moving PCK to TPACK through online professional development. *Journal of Digital Learning in Teacher Education, 27*(2), 42-52.

Padmavathi, M. (2017). Preparing teachers for technology based teaching-learning using TPACK. *İ-managers Journal of School Educational Technology*, *12*(3), 1-10.

Pamuk, S. (2012). Understanding preservice teachers' technology use through TPACK framework. *Journal of Computer Assisted Learning*, *28*(5), 425-439.

Polly, D., Mims, C., Shepherd, C., & Inan, F. (2010). Evidence of impact: Transforming teacher education with preparing tomorrow's teachers to teach with technology (PT3) grants. *Teaching and Teacher Education 26*(4) 863-870.

Rehmat, A. P., & Bailey, J. M. (2014). Technology integration in a science classroom: Preservice teachers' perceptions. *Journal of Science Education and Technology, 23*(6), 744-755.

Richardson-Kemp, C., & Yan, W. (2003). Urban school teachers' self-efficacy beliefs and practices, innovation practices, and related factors in integrating technology. In *Society for Information Technology & Teacher Education International Conference* (pp. 1073-1076). Chesapeake, VA: Association for the Advancement of Computing in Education.

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK) the development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, *42*(2), 123-149.

Shin, T., Koehler, M., Mishra, P., Schmidt, D., Baran, E., & Thompson, A. (2009). Changing technological pedagogical content knowledge (TPACK) through course experiences. In C. Crawford et al. (Eds.), *Proceedings of Society for Information Technology and Teacher Education International Conference* (pp. 4152-4159). Chesapeake, VA: AACE.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1-23.

Tabachnick, B. G., & Fidel, L. S. (2019). *Using multivariate statistics* (7th Ed.). Boston: Pearson.

Thorndike, R. M. (2005). *Measurement and evaluation in psychology and education.* Upper Saddle River, NJ: Pearson Prentice Hall.

Tondeur, J., van Braak, J., Sang, G., Voogt, J., Fisser, P., & Ottenbreit-Leftwich, A. (2012). Preparing preservice teachers to integrate technology in education: A synthesis of qualitative evidence. *Computers & Education*, *59*(1), 134-144.

U.S. Department of Education, Office of Educational Technology. (2017). *Reimagining the role of technology in education: 2017 national education technology plan update.* Retrieved from https://tech.ed.gov/files/2017/01/NETP17.pdf

Wachira, P., & Keengwe, J. (2011). Technology integration barriers: Urban school mathematics teachers' perspectives. *Journal of Science Education and Technology*, *20*(1), 17-25.

Zhan, Y., Quan, J., & Ren, Y. (2013). An empirical study on the technological pedagogical content knowledge development of preservice mathematics teachers in China. *International Journal of Social Media and Interactive Learning Environments, 1*(2), 199-212.

Author(s) Information

Tezcan Kartal
Kırşehir Ahi Evran University
Department of Science Education,
Kırsehir, Turkey
Contact e-mail: *tkartal@ahievran.edu.tr*
ORCID ID: https://orcid.org/0000-0001-7609-3555

İrem Dilek
Kırşehir Ahi Evran University
Department of Science Education,
Kırsehir, Turkey
ORCID ID: https://orcid.org/0000-0002-5177-9291