

Mediated Effects of Technology Competencies and Experiences on Relations among Attitudes Towards Technology Use, Technology Ownership, and Self Efficacy about Technological Pedagogical Content Knowledge

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Abstract This study examined the relations of preservice science teachers' attitudes towards technology use, technology ownership, technology competencies, and experiences to their self-efficacy beliefs about technological pedagogical content knowledge (TPACK). The present study also investigated interrelations among preservice teachers' attitudes towards technology use, technology ownership, technology competencies, and experiences. The participants of study were 665 elementary preservice science teachers (467 females, 198 males) from 7 colleges in Turkey. The proposed model based on educational technology literature was tested using structural equation modeling. The model testing results revealed that preservice teachers' technology competencies and experiences mediated the relation of technology ownership to their TPACK self efficacy beliefs. The direct relation of their possession of technology to their TPACK self efficacy beliefs was insignificant while the indirect relation through their technology competencies and experiences was significant. The results also indicated there were significant direct effects of preservice teachers' attitudes towards technology use,

technology competencies, and experiences on their TPACK self efficacy beliefs.

Keywords Technological pedagogical content knowledge · Science teacher education · Technological pedagogical content knowledge for science teaching · Technological competency · Technological experience · Technological attitude · Structural equation modeling

Introduction

Integrating technology into teaching is an important focus for teacher educators—especially in this era, when technology dominates our lives and work. “It is well recognized that information and communication technologies (ICT) has great potential for improving the teaching learning process. It facilitates individualized learning and develops problem solving skills.” (Padmavathi, 2013, p. 7). Other researchers have argued that effective use of technology is vital in order to enhance students' understanding (Dori & Belcher, 2005). Technology is also very influential in increasing students' motivation and interest in learning (Khine et al., 2016). However, several research studies have showed that teachers do not integrate technology in their instruction effectively (Niederhauser & Stoddart, 2001; Smeets, 2005). For example, a survey conducted by the National Center for Education Statistics in 2009 showed that under half of teachers (43% of the 1784 surveyed elementary teachers in the USA) sometimes or often use graphics and image editing software, and only 58% of them use technology for making presentations. Additionally, 24% of those surveyed use simulations and visualization programs rarely, while 33% use them often. Teachers' lack of skills and knowledge for effective technology integration may be one of the reasons for this (Eteokleous,

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2008); their beliefs about how to teach and how to learn, and contextual conditions, also direct teachers' technology integration (Boschman, McKenney, & Voogt, 2015). Clearly, technology integration in teaching is a complex process, influenced by many factors.

Mishra and Koehler (2006) put forward the Technological Pedagogical Content Knowledge (TPACK) framework and stated that teachers need to have not only content, pedagogy, and technology knowledge, but also the complex interaction between and among these three knowledge components to integrate technology into instruction effectively. The TPACK framework is frequently used to determine how to integrate technology into effective teaching strategies and to design ICT-integrated pedagogy courses (Chai et al., 2013). Technology integration is affected by different teacher-related factors—e.g., teachers' beliefs and attitudes (Blackwell et al., 2014, 2016; Hermans et al., 2008; Inan & Lowther, 2010; Karaca et al., 2013; Poyo, 2016; Sang et al., 2010; Teo, 2009), technology competency (Pelgrum, 2001), and computer ownership (Padmavathi, 2013)—and school-related factors, such as the availability of computers at school (Pelgrum, 2001) and technical support provided by the school (Blackwell et al., 2014; Mumtaz, 2005; Pelgrum, 2001).

Considering the importance of TPACK for technology integration in teaching, the present study addressed preservice science teachers' self-efficacy beliefs regarding TPACK. Self-efficacy beliefs influence behavior and choices (Bandura 1977). Several studies have pointed to the importance of teachers' self-efficacy beliefs about technology integration in their future use of technology in instruction (Abbitt, 2011; Al-Awidi & Alghazo, 2012; Al-ruz & Khasawneh, 2011; Chen, 2010; Koh & Frick, 2009; Lee & Lee, 2014; Sang, et al., 2010; Teo, 2009; Wang et al., 2004). Considering the influential role of self-efficacy in technology use, this study aimed to identify how teacher-related factors such as preservice teachers' attitudes towards technology, their technological competency, the frequency of technology use in their daily life, and their computer ownership status influenced their self-efficacy about technological pedagogical content knowledge. The results of the study will be helpful in building a more comprehensive picture of methods that promote preservice teachers' technology integration. The following research questions were tested using a structural equation modeling relied on previous research.

1. How are preservice teachers' attitudes towards technology, their technological competency, frequency of technology use in their daily life, and computer ownership related to their self-efficacy beliefs about TPACK?
2. How are preservice teachers' attitudes towards technology, their technological competency, frequency of technology use in their daily life, and computer ownership inter-related to each other?

Theoretical Framework

Regarding the integration of technology into teaching, Schmidt, Baran, Thompson, Mishra, Koehler, and Shin stated, "TPACK is a useful frame for thinking about what knowledge teachers must have to integrate technology into teaching and how they might develop this knowledge" (2009, p. 125). TPACK is also an analytical framework able to examine how components of TPACK within the results are related to each other (Chai et al., 2013), how they form TPACK (Chai, et al., 2013b), and how participants' pedagogical strategies, such as case development for teaching, develop (Mouza and Karchmer-Klein 2013). In a similar vein, Chai et al. (2013) claimed that the TPACK framework directs researchers and educators' attention to the components necessary for teaching with technology to address teachers' difficulties in integrating technology into their teaching. After having used TPACK as a lens to examine teachers' technology integration in their teaching and to design pre- and in-service teacher education programs and courses, our experiences directed us to examine the construct and the factors affecting it in detail in this research. In the following theoretical framework, we first provide details about the TPACK construct and its components. Then, we summarize the research results regarding factors (e.g., attitudes towards use of technology and self-efficacy) affecting TPACK development.

Technological Pedagogical Content Knowledge Framework

In recent years, the Technological Pedagogical Content Knowledge framework (TPACK) has received great attention. According to this framework, technological knowledge alone is not enough for effective integration of technology in teaching; teachers should also have the necessary content and pedagogical knowledge (Mishra & Koehler, 2006). The creators of the framework suggest that "at the heart of good teaching with technology are three core components: content, pedagogy, and technology, plus the relationships among and between them." (Koehler & Mishra, 2009, p. 62). Therefore, the interplay among the knowledge types—technological content knowledge (TCK), pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK)—is perhaps as important as the content knowledge (CK), technology knowledge (TK), and pedagogical knowledge (PK) (Mishra & Koehler, 2006; Koehler & Mishra, 2009; Koehler et al., 2007). Knowledge of concepts, facts, and theories within a specific subject (such as physics, chemistry, etc.) make up CK (Shulman, 1986). TK refers to the skills and knowledge required to use both advanced technology such as the Internet, electronic spreadsheets, word processors, etc., and low-level technology such as chalk and blackboards (Mishra & Koehler, 2006). General pedagogy knowledge areas such as

knowledge about classroom management strategies, how students learn, and how to assess and evaluate students are included in the definition of PK (Mishra & Koehler, 2006). PCK is a construct that “represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction” (Shulman, 1987, p. 8). TCK involves knowledge about the appropriate use of technology in the instruction of a specific topic, e.g., using simulations in the teaching of electrochemistry (Mishra & Koehler, 2006; Koehler & Mishra, 2009). TPK is knowledge about the presence of different technologies that can be used in teaching and how technology use can influence teaching and instruction in general without considering its impact on the specific content (Mishra & Koehler, 2006). TPACK is the “knowledge of using various technologies to teach and/or represent and/or facilitate knowledge creation of specific subject content” (Chai, et al., 2013). Complex interactions among CK, PK, and TK form TPACK (Koehler & Mishra, 2009).

Strengths and Weaknesses of TPACK

Integrating technology into teaching is not an easy process (Mishra & Koehler, 2006). Although the TPACK framework has offered a list of knowledge components that should be taken into account, it only focuses on knowledge types. However, in addition to knowledge, many other factors, including teachers’ beliefs about technology use and teaching, the learning context, and technology ownership, determine to what extent teachers use technology to increase their effectiveness. In their recent research, Voogt and his colleagues define TPACK as “the whole knowledge and insights that underlie teachers’ action with technology in practice” (2016, p. 38). Thus, this point is a weakness of the TPACK framework. Additionally, in the model, the three knowledge bases (i.e., TK, PK, and CK) seem to have equal weight in constructing TPACK, which may not be the case. Although it has weaknesses, the framework is still useful for shedding light on the knowledge bases necessary to integrate technology and finding pathways to develop teachers’ TPACK for conceptual science teaching (i.e., from knowledge bases to intermediary knowledge types such as TPK, TCK, and PCK). The inclusion of content in the TPACK framework makes technology integration discipline-specific (Mishra & Koehler, 2006), which is beneficial because teachers and teacher educators need to focus on the technology that is most useful for their specific discipline. To teach a conceptual understanding of science, according to the TPACK framework, teachers need to focus on learners’ difficulties (e.g., visualization of particles) in learning science topics (e.g., dissolution of NaCl salt in water), determine how to help learners overcome their issues, then look for technological applications and integrate them into the lesson. Thus, TPACK is fruitful in helping learners, teachers, and teacher educators in solving instructional problems.

Factors Influencing TPACK

One of the factors influencing TPACK is the teacher’s beliefs and attitudes towards use of technology in the classroom. Forssell (2011) showed that there was a positive correlation between attitudes towards use of technology in the classroom and TPACK scores—teachers with positive attitudes towards technology use have higher TPACK scores. Many research studies have also shown that teachers who believe that technology use in the classroom will enhance students’ understanding tend to integrate technology into their instruction (Inan & Lowther, 2010; Karaca, et al., 2013; Teo, 2009). Path analysis results revealed a significant direct relationship between teachers’ attitudes and their computer use in instruction (Hermans, et al., 2008; Karaca, et al., 2013; Inan & Lowther, 2010; van Braak et al., 2004).

In addition to attitude, another affective variable, self-efficacy, is strongly influential in teachers’ use of technology in their classrooms. Self-efficacy is described as “people’s judgments of their capabilities to organize and execute courses of action required to attain designated types of performances” (Bandura, 1986, p. 391). Self-efficacy beliefs are influential in determining the behaviors and choices of individuals. For example, highly efficacious people are more enthusiastic in dealing with a task; therefore, they do not give up when faced with obstacles, whereas less efficacious people are more anxious about the task and they do not put much effort into dealing with it (Schunk, 1981; Schunk et al., 1987). Similarly, teachers’ self-efficacy beliefs about technology will influence their technology integration in the classroom (Albion, 1999; Compeau & Higgins, 1995). If they have high self-efficacy beliefs about technology, they will be less anxious and tend to integrate technology more in their instruction (Compeau & Higgins, 1995). Likewise, if teachers believe in their competence in TPACK, they will be more inclined to integrate technology into their instruction effectively (Lee & Tsai, 2010). Though the TPACK framework has been considered fruitful for the design of teacher education and professional development programs for effective technology integration (Chai et al., 2010; Niess, 2005; Niess et al., 2006), one of the issues that is rarely explored in the related literature is the need to reveal the factors influencing preservice science teachers’ self-efficacy beliefs about TPACK. It is crucial to explore these factors, because this knowledge can then be used to redesign teacher education programs. Abbitt (2011) studied the relationship between preservice teachers’ TPACK and their self-efficacy beliefs regarding technology integration. Increased technological pedagogical content knowledge tends to correlate with more self-efficacy beliefs. Considering this relationship, we believe that factors influencing preservice teachers’ TPACK will also have an impact on their self-efficacy beliefs regarding TPACK.

Technology competency, or having the necessary skills and knowledge required for use of technology, is another factor influencing teachers' integration of technology in their instruction (Hew & Brush, 2007; Kabakci-Yurdakul & Çoklar, 2014; Karaca et al., 2013; Pelgrum, 2001). Pelgrum (2001) reported that teachers' lack of skills and knowledge regarding technology was an obstacle to their ability to use technology in teaching. Karaca et al. (2013) found that teachers' technology competency had a significant and positive direct relationship with technology integration. A direct relationship between computer competency and technology integration was also reported by several other researchers (e.g., Robinson, 2003 as cited in Inan & Lowther, 2010; Mathews & Guarino, 2000 as cited in Inan & Lowther, 2010). In terms of the relationship between technology competency and TPACK, Forsell (2011) stated that teachers' skills related to the Internet were positively correlated with their TPACK scores. However, in that research, definitions of teachers' competency were restricted to Internet ability. As Jamieson-Proctor et al. (2010) state, teachers' technology competency can also be a measure of technology knowledge (TK). In the related literature, teachers' technology knowledge is found to affect their TPACK (Koh et al., 2013).

Regarding the relationship between technology competency and one's attitude towards use of technology in instruction, some research studies have shown that technology competency affects teachers' attitudes (Albirini, 2006; Inan & Lowther, 2010; Karaca et al., 2013). Albirini (2006) found teachers' technology competency was a significant predictor of their attitudes towards technology. According to a 2010 study by Inan and Lowther, teachers' computer proficiency was positively related to their beliefs about technology use in instruction. Karaca et al. (2013) also confirmed the direct positive relationship between teachers' technology competency and their attitudes towards technology use in instruction.

Frequency of technology use by teachers in their personal life, which is an indicator of technology experience, is also reported to be correlated with technology integration (Forsell, 2011; Hermans et al., 2008; Van Braak et al., 2004). Teachers who use computers more frequently in their personal lives tend to have more confidence in their TPACK. Van Braak et al. (2004) reported direct influence of intensity of computer use on the technology integration in the classroom. Teachers who use computers at home also integrate technology into their instruction (William et al., 2000). Similarly, in a study by Wozney et al. (2006), teachers' personal use of computers was found to be a significant predictor of their technology integration in the classroom.

Computer experience and computer competency are also related. Van Braak (2004) mentioned the direct influence of the intensity of computer use on university students' computer competency. Karaca et al. (2013) stated that teachers' duration of computer use in years, which is an indicator of computer

experience, is also related to their technology competencies. The more years teachers use computers, the more competencies they have regarding technology. In terms of the relationship between individuals' computer experience and their attitudes towards computers, Levine and Donitsa-Schmidt (1998) stated that students who use computers more frequently in their daily life tend to have more positive attitudes about the use of computers as educational tools. Mitra (1998) also confirmed this by revealing the positive relationship between students' frequency of computer use and their attitudes towards computers. Cavas et al. (2009) revealed the effect of science teachers' computer experience on their attitudes towards technology in instruction. Teachers who had used computers for more than 5 years were significantly different in their attitudes from the teachers who had used computers a fewer number of years.

Technology ownership also influences teachers' technology integration. Padmavathi (2013) stated the significant effect of computer ownership on teachers' use of computers in class. Teachers who owned computers at home tended to integrate technology into their teaching. Computer ownership at home is also found to be associated with teachers' attitudes. Cavas et al. (2009) found computer ownership had a significant effect on teachers' attitudes towards ICT. They stated that science teachers who owned a computer had more positive attitudes towards use of ICT in teaching. Kutluca (2010) confirmed this finding by indicating that teachers who own computers at home tend to have more positive attitudes towards technology. Moreover, computer ownership at home is related to technology competency; that is, people who have a computer at home have more computer skills and competency (Norzaidi et al., 2007; Tyler-Wood et al., 1997). Computer ownership at home is positively associated with people's frequency of technology use as well (Baloglu & Cevik, 2008).

Summary of the Related Literature

It is clear that different factors influence teachers' technology use in teaching. Analysis of direct and indirect relations among those factors and self-efficacy about TPACK in the single model will be worthwhile for comprehensively understanding the nature of the problem.

Based on the studies cited above, we can conclude that preservice science teachers' attitudes towards use of technology in teaching, their technology competencies, the frequency of technology use in their life, and their computer ownership are directly related to their perceived TPACK. Preservice teachers' frequency of computer use, computer competency and computer ownership also have a direct influence on their attitudes towards technology. Frequency of computer use and computer ownership status are directly related to the technology competency, while computer ownership influences frequency of computer use directly. Therefore, we proposed the model shown in Fig. 1.

Method

This study is quantitative in nature. The hypothesized model represented in Fig. 1 was constructed based on TPACK literature. The model was tested using structural equation modeling (SEM). SEM was chosen for data analyses because it has several advantages over other general linear models, such as regression analysis and ANOVA. First, SEM enables researchers to test quantitatively complex theoretical models, including latent and observed variables. That is, SEM allows testing of inter-relationships among constructs and observed variables. Second, it increases the reliability of data analysis by considering measurement errors of the variables in the model (Hu and Bentler 1999; Weston and Gore 2006; Schumacker and Lomax 2010). Finally, it allows researchers to analyze direct and indirect relations among variables, which leads to the determination of possible mediating variables. The proposed model was tested with LISREL 8.8. For reliable and valid SEM analysis, necessary assumptions for SEM, discussed in the “Results” section, were checked before the analyses. The analyses were carried out based on a covariance matrix with the maximum likelihood estimation method. Multiple fit indexes—Chi-square/degrees of freedom (χ^2/df), Normed Fit Index (NFI), Comparative Fit Index (CFI), root mean square error of approximation (RMSEA), and standard root mean square residual (SRMR)—were employed to assess whether the model fit the data. The cutoff criteria recommended by Schreiber et al. (2006) for these fit indexes were taken into consideration in the present study. According to the cutoff values, an acceptable fit is represented by $\chi^2/df \leq 3$, NFI ≥ 0.95 , CFI ≥ 0.95 , RMSEA < 0.06 to 0.08 , with confidence interval SRMR ≤ 0.08 . The effect size for magnitudes of standard regression coefficients were evaluated using cutoff values

suggested by Kline (1998). According to these values, a coefficient less than 0.10 was taken as a small effect size, a coefficient around 0.30 was considered as medium effect size, and a coefficient larger than 0.50 was considered as large effect size. Finally, the effect size for magnitude of explained variances (R^2) on dependent variables was evaluated using cutoff values ($R^2 \leq 0.01$, small effect size; R^2 around 0.09, medium effect size; $R^2 \geq 0.25$, large effect size) recommended by Cohen and Cohen (1983).

Participants

In this research, the data were collected from 665 preservice elementary science teachers in their last year of studies (467 female, 198 male). We studied participants from seven colleges that differed regarding the geographical area, size of cities, and accessibility to ICT. In Turkey, we have seven geographical areas formed according to their climate, geographical boundaries, and culture. In this study, we collected data from three areas. The method of sampling was convenience sampling; however, to reduce the biases due to convenience sampling, we paid specific attention to choosing universities with different characteristics (i.e., regarding the geographical area, large and small cities, and the accessibility to ICT) (Fraenkel and Wallen 2006).

Participants were senior preservice teachers enrolled in 4-year elementary science teacher education programs that all had content courses (e.g., physics, chemistry, and biology), pedagogy (e.g., classroom management), content-specific pedagogy courses (e.g., elementary science teaching methods course), ICT courses, and a practicum. When the data were collected (June 2014), the participants had completed most of the content and pedagogical courses and all the ICT courses. In other words, the participants had almost graduated at the time the data were collected.

Due to the need to collect data from different colleges of education, we requested that our peers administer the instruments in their own Elementary Science Education departments. We shared our purpose and told them how to administer the data sources and the information that needed to be given to the participants, etc. We copied the instruments and mailed them to the peers who agreed to collect data.

Instruments

TPACK Self-Efficacy Scale Data were collected by the use of the TPACK self-efficacy scale (TPACK-SeS) developed by Canbazoglu Bilici et al. (2013). Canbazoglu-Bilici and her colleagues (2013) developed the instrument by collecting data from 808 preservice teachers enrolled in 17 universities. They reported that the reliability coefficients were between 0.84 and 0.94 for the factors under TPACK-SeS. CFA and EFA showed that TPACK-SeS is a valid and reliable instrument to measure TPACK self-efficacy. The scarcity of instruments in the Turkish language, the

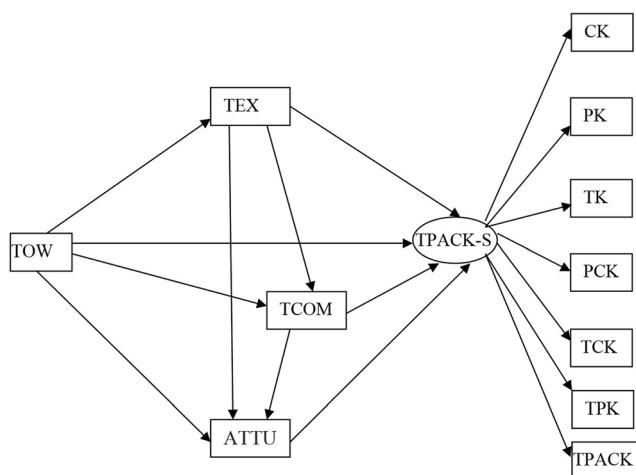


Fig. 1 The hypothesized model in the present study. *ATTU* attitudes towards technology use, *TEX* technology experience, *TCOM* technology competency, *TOW* technology ownership, *TPACK-S* TPACK self-efficacy

Table 1 Example items from TPACK-SeS

Factor	Example item
PK	I can manage my classroom effectively.
CK	I can explain various biology concepts.
TK	I can use software.
PCK	I can teach science and technology courses according to theoretical framework of national curriculum.
TPK	I can determine technologies that are appropriate for students’ grade level.
TCK	I can use technological tools (e.g., spreadsheets, computer) to analyze scientific data.
TPCK	I can use technological tools to assess student learning of science.

TPACK-SeS’ high reliability coefficients and good evidence for its validity, the inclusion of TPACK sub-components, and its being specific to the field of science were all contributing factors in our decision to use this scale.

The instrument has five-point Likert-type items, the score of which ranges from 1 (cannot do at all) to 5 (highly certain can do). Table 1 presents example items from different factors of TPACK-SeS.

Technology Competencies, Technology Experiences, and Attitudes Towards Technology Use Scales The technology competencies (TCOM) scale (11 items) was developed by Karaca et al. (2013). It uses five-point Likert-type items. For the TCOM, participants were asked to rate how competent—i.e., not competent (1) to very competent (5)—they are in using the technologies put forth in the items (e.g., computer, the Internet, printer, PowerPoint, Excel, etc.). For TCOM, Karaca et al. (2013) reported a 0.93 Cronbach’s alpha reliability coefficient. For technology experiences (TEX), participants were asked to rate how frequently they use the technology provided in the items. TEX was based on a five-point rating scale that ranged from “not at all” to “always.” TEX included the same 11 items that TCOM had; we formed the TEX based on the TCOM scale developed by Karaca et al. (2013).

The attitudes towards technology use (ATTU) scale (seven items) developed by Karaca et al. (2013) was used as well. Table 2 provides necessary details about ATTU. Similarly to our choice of TPACK-SeS, we utilized those instruments due to the scarcity of instruments in Turkish and the strong evidence of reliability and validity that they provided.

Additionally, demographic questions and questions about owning a computer (TOW) were asked to the participants. All instruments were administered to the participants simultaneously after getting necessary permissions from the review board.

Table 2 Details about ATTU

Example items	Ranges
The use of technology increases students’ participation to the lessons.	1–5 (strongly disagree–strongly agree)
The use of technology increases the permanency of the learning.	

Results

Checking Assumptions for SEM

Researchers should meet the assumptions of SEM to be able to conduct reliable SEM analyses (Schreiber et al., 2006; Weston & Gore, 2006). Therefore, the required assumptions of SEM were checked before carrying out the analysis. There were 665 elementary preservice science teachers included in the present study; thus, sample size of the study was larger than the minimum recommended sizes (Barrett, 2007; Weston & Gore, 2006).

Table 3 indicates descriptive statistics and reliability coefficients of the measured variables in the study. All Cronbach’s alphas are greater than 0.70, which is suggested as a cutoff value for reliable scale (Pallant, 2001). All means of the measured variables are greater than the mid-point of five-point Likert scales. Normality and outlier assumptions were also required for SEM. According to skewness, kurtosis, and 5% trimmed mean values, the data were normally distributed and there were no severe outliers (Kline, 2005; Pallant, 2001). There was no multicollinearity problem since, as indicated in Table 4, inter-correlations among the measured variables were less than 0.90 (Pallant, 2001).

Table 4 demonstrates the inter-correlations among observed variables in the model. The correlations among observed variables ranged from 0.11 to 0.82. The most-related variables were TPK and TPACK, while the least-related variables were technological competency (TCOM) and attitudes towards technology use (ATTU).

The Measurement Model of TPACK-S

The measurement model of TPACK-S, which is a part of the proposed structural model, was tested before testing the whole

Table 3 Descriptive statistics and Cronbach's alphas of the measured variables

Measured variables	Number	Mean	SD	5% Trimmed mean	Skewness	Kurtosis	Cronbach's alpha
1. TCOM	665	3.11	0.82	3.12	-0.14	0.19	0.87
2. TEX	665	2.93	0.68	2.93	0.03	0.47	0.85
3. ATTU	665	4.15	0.68	4.21	-1.38	3.27	0.90
4. TOW	665	1.75	0.32	1.78	-0.93	0.23	–
5. CK	665	3.31	0.67	3.31	0.03	0.38	0.87
6. PK	665	3.52	0.69	3.52	0.01	0.21	0.91
7. TK	665	3.09	0.91	3.09	0.01	-0.33	0.91
8. PCK	665	3.47	0.67	3.46	-0.02	0.18	0.94
9. TCK	665	3.37	0.78	3.37	-0.07	-0.20	0.83
10. TPK	665	3.52	0.69	3.52	-0.07	0.14	93
11. TPACK	665	3.33	0.75	3.33	-0.07	0.14	0.91

structural model. Testing measurement part of a model separately helps researchers to specify whether a model has poor fit because of the measurement model, the structural model itself, or both (Anderson and Gerbing 1988; Jöreskog and Sörbom 1993). In the first testing, fit indexes were not within the acceptable level. According to modification indices, the errors of the related components of TPACK-S were left to be correlated. After that, the measurement model fit the data ($\chi^2(7, N = 665) = 18.88$, $\chi^2/df = 2.68$, NFI = 0.99, CFI = 0.99, RMSEA = 0.05 (90% CI = 0.02, 0.08), SRMR = 0.01). All fit indexes are within the acceptable range considering cutoff values suggested by Schreiber et al. (2006). Standardized coefficients, standard errors, *t* values, and explained variances for the Measurement Model of TPACK-S are presented in Table 5. All regression coefficients from TPACK-S to its components are significant ($p < 0.05$). All R^2 s are significantly larger than 0.25, which is the value of threshold for large effect size (Cohen & Cohen, 1983). In conclusion, these results support a seven-factor structure of TPACK-S.

Testing Hypothesized Model

In the second part of the analysis, other proposed paths were added to the confirmed measurement model of TPACK-S and this model was tested. According to the fit indexes, the model had an acceptable fit ($\chi^2(31, N = 665) = 134.500$, $\chi^2/df = 4.34$, NFI = 0.99, CFI = 0.99, RMSEA = 0.07 (90% CI = 0.06, 0.08), SRMR = 0.04). All values of fit indexes, except for χ^2/df , were in the acceptable range according to cutoff values of Schreiber et al. (2006). χ^2/df was over 3, the cutoff value proposed by Schreiber et al. (2006). However, some researchers (e.g., Kabakci-Yurdakul et al. 2012; Marsh and Hocevar 1985) suggest 5 as a cutoff value for a reasonable fit. Therefore, we can say that all fit indexes were in the acceptable range. Figure 2 demonstrates the final model with direct path coefficients, insignificant paths with dashed lines, and the explained variances (R^2).

All proposed regression paths in the model were statistically significant except for the paths from TOW to TPACK-S, from TOW to ATTU, and from TCOM to ATTU. In the

Table 4 Zero-order correlations among measured variables in the study

Measured variables	1	2	3	4	5	6	7	8	9	10	11
1. TCOM	1										
2. TEX	0.73	1									
3. ATTU	0.11	0.14	1								
4. TOW	0.30	0.31	0.02	1							
5. CK	0.36	0.39	0.15	0.17	1						
6. PK	0.38	0.42	0.26	0.13	0.60	1					
7. TK	0.56	0.55	0.16	0.26	0.53	0.50	1				
8. PCK	0.41	0.42	0.26	0.18	0.72	0.77	0.56	1			
9. TCK	0.56	0.56	0.22	0.26	0.64	0.64	0.74	0.72	1		
10. TPK	0.48	0.47	0.28	0.19	0.65	0.69	0.64	0.80	0.79	1	
11. TPACK	0.46	0.45	0.21	0.20	0.66	0.65	0.61	0.79	0.75	0.82	1

Table 5 Standardized coefficients, standard errors, *t* values, and explained variances for measurement model

Observed variables	Standardized coefficient	Standard error	<i>t</i> value	<i>R</i> ²
CK	0.74	0.14	21.36	0.54
PK	0.76	0.16	22.40	0.58
TK	0.70	0.16	19.71	0.49
PCK	0.84	0.22	25.29	0.70
TCK	0.87	0.10	27.11	0.75
TPK	0.90	0.15	28.94	0.81
TPACK	0.87	0.12	26.52	0.75

model, 42% of variance in TPACK-S was accounted for by TOW, TCOM, TEX, and ATTU. This can be considered as a large effect size (Cohen & Cohen, 1983).

The Direct, Indirect, and Total Relations among the Observed Variables and TPACK-S

Table 6 shows the direct and the indirect effects of the observed variables on TPACK-S, as well as the interrelations among observed variables. In the proposed model, it was hypothesized that all observed variables had a significant direct effect on TPACK-S. However, the direct effect of TOW on the TPACK-S was not statistically significant ($\beta = 0.05, p > 0.05$). On the other hand, the indirect effects of TOW on TPACK-S ($\beta = 0.19, p < 0.05$) through TCOM and TEX were significant, which changed the total effect of TOW on TPACK-S. This indirect relation to TPACK-S led the total effect of TOW on TPACK-S to be significant ($\beta = 0.24, p < 0.05$). That is, TCOM and TEX mediated the relations of TOW to TPACK-S.

Moreover, TEX was significantly associated with TPACK-S ($\beta = 0.31, p < 0.05$). The indirect effect of TEX on TPACK-S via TCOM was significant ($\beta = 0.25, p < 0.05$), which increased the total effect of TEX on TPACK-S ($\beta = 0.56, p < 0.05$). The effect size of the direct effect is medium, whereas that of the total effect is large. TCOM was significantly related to TPACK-S ($\beta = 0.31, p < 0.05$). Finally, ATTU had significant direct effect on TPACK-S ($\beta = 0.20, p < 0.05$).

The Interrelations Among the Observed Variables of the Study

TOW had significant direct relations to TEX ($\beta = 0.31, p < 0.05$) and to TCOM ($\beta = 0.09, p < 0.05$), whereas it did not have significant direct relations to ATTU ($\beta = -0.03, p > 0.05$). On the other hand, indirect effects of TOW on ATTU ($\beta = 0.05, p < 0.05$) through TCOM and TEX were significant, which changed total effects. Direct effect of TOW on ATTU was negative. Indirect positive relation through TCOM and TEX to ATTU, however, turned the negative relation to a positive relation ($\beta = 0.02, p > 0.05$). That is, TCOM and TEX mediated the relation of TOW to ATTU.

TEX was significantly associated with TCOM ($\beta = 0.70, p < 0.05$) with a large effect size and with ATTU ($\beta = 0.14, p < 0.05$) with a small effect size. TCOM was not significantly associated with ATTU ($\beta = 0.02, p > 0.05$).

In terms of the explained variance of the dependent variables, TOW and TEX accounted for 53% of the variance of TCOM. TOW explained 10% of the variance of TEX. On the other hand, only 2% of the variance of ATTU was explained by TEX, TOW, and TCOM collectively.

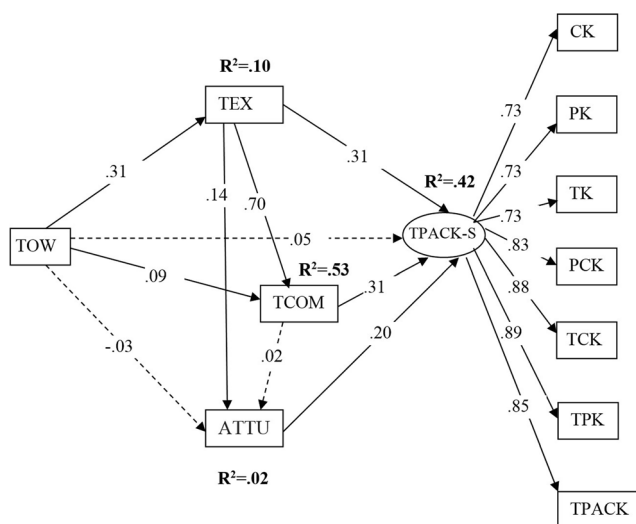


Fig. 2 The tested structural model. ATTU attitudes towards technology use, TEX technology experience, TCOM technology competency, TOW technology ownership, TPACK-S TPACK self-efficacy

Conclusion, Discussion, and Implications

In this study, we focused on factors (i.e., belief and skills) influencing preservice teachers’ self-efficacy beliefs related to TPACK by the use of SEM. It was found that preservice science teachers’ attitudes towards technology use, their technology competencies, and their experiences had direct influence on their self-efficacy beliefs in terms of TPACK. These results support the findings reported in other technology

Table 6 Path coefficients, standard errors, and *t* values for direct, indirect, and total effects

Variables		TEX			TCOM			ATTU			TPACK-S		
		Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
TOW	β	0.31	–	0.31	0.09	0.22	0.31	–0.03	0.05	0.02	0.05	0.19	0.24
	SE	0.43	–	0.43	0.40	0.39	0.52	0.30	0.11	0.29	0.05	0.04	0.06
	<i>t</i>	8.38	–	8.38	3.07	7.95	8.16	–0.837	3.33	0.38	1.54	7.19	6.04
TEX	β	–	–	–	0.70	–	0.70	0.14	0.01	0.15	0.31	0.25	0.56
	SE	–	–	–	0.03	–	0.03	0.04	0.03	0.03	0.01	0.01	0.01
	<i>t</i>	–	–	–	25.02	–	25.02	2.42	0.36	3.73	6.38	6.88	13.80
TCOM	β	–	–	–	–	–	–	0.02	–	0.02	0.31	0.01	0.32
	SE	–	–	–	–	–	–	0.03	–	0.03	0.01	0.01	0.01
	<i>t</i>	–	–	–	–	–	–	0.36	–	0.36	6.51	0.36	6.42
ATTU	β	–	–	–	–	–	–	–	–	–	0.20	–	0.20
	SE	–	–	–	–	–	–	–	–	–	0.01	–	0.01
	<i>t</i>	–	–	–	–	–	–	–	–	–	6.01	–	6.01

integration studies (e.g., Blackwell et al., 2014, 2016; Lee & Lee, 2014; Hew & Brush, 2007; Inan & Lowther, 2010; Teo, 2009; Van Braak et al., 2004; William et al., 2000). Based on the results of this study, it can be said that the more teachers have technological skills and experiences, the higher probability that they have higher self-efficacy beliefs about TPACK. Cox et al. (1999) stated that teachers who frequently used technology had high confidence and believed in their advantages in effective teaching. Similarly, Gritter (2005) found that the most important aspect influencing teachers' computer use was technology experiences. Furthermore, teachers with more positive attitudes towards technology have higher self-efficacy beliefs about TPACK. The important role of preservice teachers' attitudes towards technology integration for their development of self-efficacy beliefs was also observed in a study by Lee and Lee (2014). They found that preservice teachers with more positive attitudes towards technology demonstrated higher increases in their self-efficacy about technology integration during a technology integration course aiming to promote preservice teachers' self-efficacy about technology integration. Thus, teacher education programs and professional development activities should focus on teachers' attitudes towards technology and aim to improve them through the preservice. For instance, Blackwell et al. (2014) found that teachers with higher perceived support from their schools demonstrated positive attitudes towards and confidence in technology integration. Similarly, Poyo (2016) investigated the effect of an online instruction module, developed based on TPACK framework, on preservice teachers' attitudes towards technology integration. In that online learning environment, students engaged in authentic experiences with technology in which they practiced with several digital tools for learning, assessing, and managing students in an online classroom. The preservice teachers' attitudes improved

significantly at the end of the intervention. Finally, the analysis of the current study also revealed that preservice teachers' possession of technology did not have a significant direct relation to their self-efficacy beliefs about TPACK. That is, having technology did not automatically lead to better TPACK self-efficacy beliefs. Furthermore, this study revealed the positive effects of preservice teachers' technology competencies and experiences on their attitudes towards technology use in instruction. Similar results were found in other studies (Albirini, 2006; Inan & Lowther, 2010; Karaca et al., 2013; Levine & Donitsa-Schmidt, 1998).

The literature revealed that interventions in which preservice teachers were actively involved in the technology integration process promoted the participants' self-efficacy beliefs about technology integration (Lee & Lee, 2014; Heo, 2009; Koh & Frick, 2009; Wang et al., 2004). Koh and Frick (2009) documented the patterns of classroom experiences most effective for improving preservice teachers' self-efficacy about technology integration. Instructor demonstrations that were enriched with prompts and hints, the checking of student progress during project work in the lab, and the prompting of students to discuss and share their projects and ideas were found to increase preservice teachers' self-efficacy in technology integration. Lee and Lee (2014) designed an intervention study to improve preservice teachers' self-efficacy beliefs about technology integration through a technology integration course. They investigated which of the course factors—including instructional media development skills, knowledge of technology (provided through lectures), and lesson planning practice—had the greatest influence on self-efficacy beliefs. They also tested the direct and indirect effects of computer use and teachers' attitudes towards computers on changes in their attitudes about their self-efficacy with a path analysis. They found that the course, especially lesson practice

activities, promoted students' self-efficacy. That is, when preservice teachers were required to link technology knowledge with curriculum and instructional methodology, their self-efficacy about technology-integrated instruction improved (Lee & Lee, 2014).

The present study also investigated indirect relations among the variables. This revealed mediating variables. Although technology possession did not directly affect preservice teachers' self-efficacy about TPACK, the indirect effect of technology ownership on their self-efficacy through its effects on technological competencies and experiences was significant, which turned an insignificant relation into a significant total relation. As stated before, on its own, having technology is not adequate to raise self-efficacy beliefs about TPACK. It is also vital to have the necessary skills required for the use of that technology and to frequently use it for teaching purposes. Teachers' technology competencies can be promoted by providing user-friendly software and support to them (Youngman & Harrison, 1998).

The mediator role of preservice teachers' technology competencies and experiences was also observed with respect to the relationship of technology ownership to participants' attitudes towards technology use in instruction. Interestingly, in our sample, the direct relation between technology ownership and technological attitude was negative. When their technological competencies and experiences were not taken into account, the teachers with technology demonstrated negative beliefs towards technology use. That is, participants with less experience and fewer of the required skills to use technology effectively demonstrated negative attitudes about technology integration into teaching. On the other hand, when participants had adequate competencies and experiences related to technology, the negative attitude disappeared and they appreciated the usefulness of technology in instruction.

The present study has several implications for preservice teacher education. It is important to improve teachers' attitudes towards technology in instruction. This can be achieved when they have a chance to observe their mentors using technology effectively (i.e., vicarious experience) or when preservice teachers use technology in their own instruction during the practicum (i.e., mastery experience). Teacher educators should help teachers to see the benefits of technology through small steps in which support and user-friendly software are provided. For example, science teacher educators should use science-specific applications and programs in their content courses to make them more conceptual, which will allow preservice science teachers to see how technology is helpful in understanding science concepts. Moreover, preservice teachers should gain more experience in using technology; this could be achieved by offering more courses that include assignments and projects based on or incorporating technology's use in teaching science. This not only improves their attitudes, but also increases their technological

competencies and experiences. For instance, in our science teacher education program for preservice teachers, we offered an elective "technology integration" into our science teaching course, including 2 h of both theoretical and practical sessions per week. Based on our observations of students' reactions and behaviors, such courses can be effective in developing TPACK for teaching science and positive attitudes towards technology use in science teaching.

Design-based learning can also be useful in providing experience to preservice teachers (Baran and Uygun 2016). In this approach, teacher educators may ask preservice teachers to criticize a lesson plan that includes technology use. Alternatively, preservice teachers may plan a lesson integrating technology and then perform it in microteaching sessions (Baran and Uygun 2016). Due to the fact that TPACK focuses on the use of technology to teach a specific discipline, a science teaching method course can be a good context to teach preservice teachers how to use technology for teaching conceptual science. In this course, science teacher educators should include examples of the use of technology (e.g., use of Algodoo for simulations to teach Physics concepts or the use of animations to explain the dissolution of solids at the particulate level). Finally, regarding ownership, as in the Youngman and Harrison (1998) project, teachers can be provided technology through the help of project grants. Teacher education programs should provide technology laboratories that are available for preservice teachers so that they can become more competent in technology and have more experience. Trainings, workshops, and scaffolding for technology integration in science teaching courses would catalyze the effect of ownership and/or technology access.

In this research, we aimed to model the relationship of preservice teachers' attitudes towards technology use, their technology ownership, technology competency, and their experience to their self-efficacy regarding technological pedagogical content knowledge. We collected the data through the use of scales. To have a more complete picture, in addition to this quantitative research, a qualitative part that examines how preservice teachers use technology in their planning and teaching should have been included. Interviews focusing on how the participants use technology for teaching elementary science topics and observations focusing on their technology use in practicum would have enriched the study and the interpretation of the results.

In conclusion, this study, which focuses on the factors affecting preservice teachers' TPACK self-efficacy, will be useful for science teacher educators to be informed about factors influencing TPACK self-efficacy. Teacher educators should take these findings into account when designing syllabi for ICT-related pedagogy courses and when facing problems related to preservice teachers' difficulties and negative attitudes towards technology use in teaching.

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