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Predicting Preservice Science Teachers' TPACK through ICT usage

Cansel Kadıoğlu-Akbulut[1] · Ayla Cetin-Dindar[2] · Burçin Acar-Şeşen[3] · Sevda Küçük[4]

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Abstract

Designing effective and efficient learning environments by integrating recent educational technologies into the teaching process has become an important goal of education for nearly two decades. However, earlier studies showed that a higher level of technology knowledge does not guarantee the development of TPACK. At this point, studies guided by the transformative approach defining TPACK as a unique knowledge revealed encouraging results for a better understanding of technology-integrated instruction. This study aims to investigate to what extent ICT usage categories predict preservice science teachers' TPACK. Totally 326 preservice science teachers with a mean age of 21.62 ($SD = 1.41$) from seven different universities participated. For that purpose, a correlational study was conducted. The ICT-TPACK-Science Scale and the ICT Usage Questionnaire were used to collect data. Six separate multiple regression analyses were conducted to predict TPACK measures using ICT measures. Results indicated that approximately a third of the variability in total-TPACK scores can be accounted for by three ICT measures. The relative importance of individual predictors is arranged in the following order desktop software, emerging ICTs, and hardware. As for the dimensions of the ICT-TPACK-Science Scale, the overall effect of the ICT predictors decreased in the following order: Designing, implementing, planning, proficiency, and ethics. Emerging ICTs made the highest contribution to the designing and proficiency dimensions; while desktop software made the highest contribution to the implementing, planning, and ethics dimensions. To sum up, this study describes the association between ICT usage and TPACK in the view of the transformative ICT-TPACK-Science framework. The utilization and transformation of ICT tools as a cognitive partner for effective and efficient science teaching in different TPACK dimensions needs further investigation.

Extended author information available on the last page of the article

Keywords Technological pedagogical content knowledge (TPACK) · Information and communication technologies (ICTs) · Teacher education · Science education

1 Introduction

Rapid changes in technologies lead to significant variations in every aspect of daily life as well as in classroom practices. Globally, educational systems are aiming to integrate new technologies into the teaching process. Since technology is embedded into our life, teachers are quite a technology literate, but the issue is to comprehend the transformative understanding of technology and to use these technologies efficiently to create an effective learning environment (for instance, using innovative approaches such as blended learning, giving an out-of-school activity to test a research question using simulations, enhance opportunities to discuss a topic using a learning management systems, encourage students to participate in activities, etc.). Therefore, there is a need for qualified teachers who can follow recent advances in educational technologies and be able to integrate them with their subject area. The question of what the characteristics of qualified teachers are has been on the agenda for a long time among educational researchers. Shulman (1986, 1987) made one of the first statements on this issue and proposed the Pedagogical Content Knowledge (PCK) construct. According to Shulman qualified teachers should not only have sufficient field knowledge but also have sufficient pedagogical knowledge and should be able to design the process of learning the subject in their field in learning environments. In the course of time, with the development of educational technologies, it has become a necessity for teachers to use these technologies in learning and teaching processes, which entails a redesign of pedagogy and teacher qualifications redefined accordingly. As a matter of fact, with the Covid-19 pandemic process, emergency remote teaching situations have occurred all over the world and teachers have started distance education and technology usage has become an inevitable feature of teaching expertise. This exceptional situation also created awareness in the wide public about the importance of using technology in education (Seufert, Guggemos, & Sailer, 2021). In this process, the importance of the ability to benefit from educational technologies in making the learning process more effective and efficient has become more evident. Technology integration in education is widely investigated, and the studies reported mainly that efficient technology integration is based on many factors (such as willingness, experience, skill, tool, etc.) (Farjon et al., 2019; Niess, 2015). Besides, based on the framework of Technological Pedagogical Content Knowledge (TPACK) proposed by Angeli and Valanides (2009) information and communication technology (ICT) is one of the significant contributors of TPACK.

The first detailed research that integrates technology and pedagogy in the field of teacher training was conducted by Pierson (2001), in which elementary teachers' technology integration practices as a function of their technology and teaching abilities. The study provided rich and descriptive data regarding teachers' technology use, and as a final remark she used the terms "technological knowledge" and "technological-pedagogical-content knowledge". Later, Mishra and Koehler (2006), as the result of their five-year study, brought the technological pedagogical content knowledge (TPACK) concept into the literature and formed its theoretical structure. They expanded Shulman's (1986) model by adding the "technology" dimension to PCK. Mishra and Koehler's (2006) TPACK framework has evolved and has guided many studies. Lately, this framework was updated by including contextual knowledge (Mishra, 2019). This theoretical approach is called the "integrative model" and researchers who adopt the integrative model argue that when development is achieved in at least one knowledge, teachers' TPACKs will also improve (Doering & Veletsianos, 2008; Doering, Veletsianos, Scharber, & Miller, 2009; Guzey & Roehrig, 2009).

Although studies are reporting the development of technology knowledge enhances the development of TPACK in terms of integrative view, there are also undeniable studies this development does not automatically result in TPACK development (Angeli & Valanides, 2005; Cetin-Dindar, Boz, Yildiran-Sonmez, & Demirci-Celep, 2018; Pamuk, 2012; Valanides & Angeli, 2008). Studies focused on integrating technology implicitly revealed that TPACK is beyond the integrative model; for instance, Pamuk (2012) expressed that the preservice teachers with adequate technological backgrounds had difficulties in integrating technology into the teaching process. Similar finding could be also found in the study of Cetin-Dindar et al. (2018); the researchers promoted emerging technologies during a semester to the preservice chemistry teachers and hypothesized to develop their TPACK, but the results did not reveal a significant development in the participants' TPACK; this indicates that expanding technology knowledge is not sufficient to be competent in TPACK. These studies showed that the development of a certain level of knowledge in pedagogy, content and technology did not contribute to the development of TPACK. The reason for this was attributed to a lack of teaching experience (Angeli & Valanides, 2008, 2009; Pamuk, 2012) criticized the integrative model as a teacher who is good at a content area or pedagogy may not be able to integrate technology into the learning process. In this context, they state that the TPACK studies based on the integrative model reveal not about the TPACK knowledge type, but the types of knowledge that constitute TPACK, and the TPACK should be considered as a whole due to the uncertain boundaries between TPACK components. They proposed the "transformative TPACK model" in which TPACK is defined as a different type of knowledge that comes together with the dynamic interactions of content, pedagogy, learners, context, and ICT knowledge bases and TPACK needs to be studied beyond the intersection of these knowledge bases.

In the last two decades, the TPACK framework has been frequently used to investigate in-service and preservice teachers' TPACK. Wu (2013) revealed that the studies mostly focused on teachers' general TPACK level and relatively less work has been conducted specifically to the teachers' subject field. Therefore, the present study focused on preservice science teachers' TPACK. In this study, the ICT-TPACK-Science framework (Kadıoğlu-Akbulut, Cetin-Dindar, Küçük, & Acar-Şeşen, 2020) was used. The models based on the transformative approach have been developed in recent years (Kadıoğlu-Akbulut et al., 2020; Kabakçı-Yurdakul et al., 2012; Yeh, Hsu, Wu, Hwang, & Lin, 2014). The ICT-TPACK-Science framework covers five dimensions (Fig. 1). The *planning* dimension covers analyzing, determining, and planning appropriate instructional technologies and pedagogical approaches in science education by considering student characteristics, time, content, objectives, students'

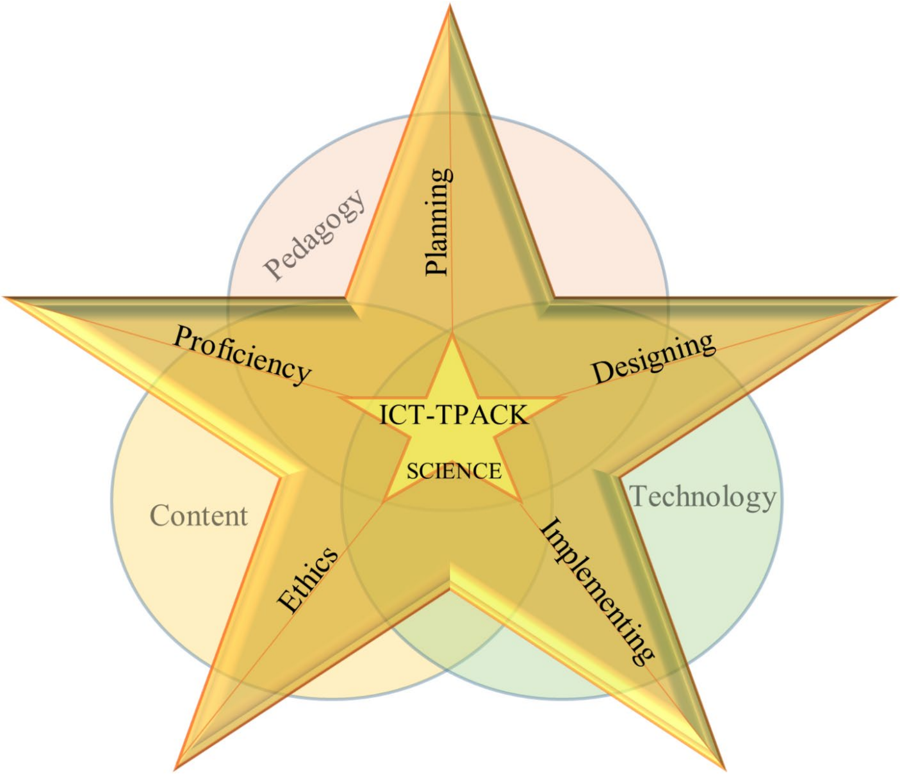

Fig. 1 ICT-TPACK-Science framework (Kadıoğlu-Akbulut et al., 2020)

readiness, teaching environment. The *designing* dimension characterizes creating/editing instructional materials using appropriate technologies in science education in terms of student needs, teaching content, or learning environment. The *implementing* dimension refers to ensuring classroom management while using various teaching technologies in the science teaching process, applying the appropriate pedagogical principles and methods based on content and individual differences, using appropriate technologies in evaluation and assessment, and using learning management systems, social networks. The *ethics* dimension includes access to technology ethically, confidentiality, and intellectual property rights, and paying attention to the teaching profession at every stage of the science teaching process. The *proficiency* dimension refers to the ability to take advantage of the technology at every stage of the science teaching process to overcome technological problems, mentor colleagues to disseminate innovative technologies, and handle interdisciplinary collaborations.

In studies investigating the TPACKs of preservice teachers from different fields according to the transformative approach, Kabakçı-Yurdakul (2011) determined that the preservice teachers perceived themselves at an advanced level in terms of technopedagogical education competencies. In the dimensions of technopedagogical education, it has been determined that they perceive themselves at an advanced level in the dimensions of design, implementation, and ethics, respectively, and they perceive themselves at a medium level in the dimension of proficiency. Besides, it was revealed that the technopedagogical education competencies of preservice teachers differ according to the level of ICT usage. Kabakçı-Yurdakul and Çoklar's (2014) study results showed that the use of ICT usage knowledge and skills of the preservice teachers affect their general TPACK competencies. Wright and Akgunduz (2018)'s study results showed that there is a significant relationship between TPACK self-efficacy belief levels and the variables involved in pre-service science teachers' use of Web 2.0 tools.

ICT competence and self-efficacy are important in ICT usage. ICT competence refers to a teacher's ability to use ICT (Aesaert & Van Braak, 2015), and it is a competency that allows teachers to effectively integrate a variety of digital resources into education (Almerich et al., 2016). The term "perceived ICT competency" refers to how preservice teachers rate their own proficiency in using particular software programs (such as Word, Excel, PowerPoint, and Photoshop) and technical abilities that may be regularly applied in their future teaching (Wang & Zhao, 2021; Tondeur et al., 2012) found that the technology experience provided by teacher preparation programs is crucial to preservice teachers' capacity for technology integration. The teachers' value beliefs about technology strongly predict their TPACK (Cheng & Xie, 2018). According to the most recent research, teachers' use of professional development tools (TPACK) was directly associated with ICT-related criteria, such as their impression of ICT support, access to ICT tools, and ICT application abilities (Farjon et al., 2019). However, limited studies have revealed a correlation between technology usage level and educational internet use and TPACK (Kazu & Erten, 2014; Sahin, Celik, Akturk, & Aydin, 2013). For more evidence, more studies are needed to conduct to understand technology transformation. Technology usage in science education is a must, even the approach is based on integrative or transformative, and ICT is evident for both models. In this study, the contribution of ICT on preservice science teachers' TPACK in terms of transformative approach was investigated.

1.1 The rationale and importance of the study

It often remains unclear what the term technology covers. The scope of technology can range from chalkboards to social robots. Indeed, technology is a very dynamic concept (Koehler et al., 2013) and with these rapid changes in technology, its applications in the educational environment are also constantly changing. Therefore, the teachers' competencies for ICT-integrated instruction should keep developing to maximize student learning. The science learning process can be made more effective, efficient, and interesting with many different ICTs, especially interactive videos, animations, simulations, virtual laboratories, and augmented reality applications. The use of ICT in education has also advanced due to the rapid development of new ICT, such as social networking sites, mobile devices, and cloud computing (Teo et al., 2019). In recent years, the use of easy-to-use Web 2.0 technologies, which allow material development and support collaboration and communication, has become very common in teaching and learning processes (Englund et al., 2017; Pollacia & McCallister, 2019; Sadaf, Newby, & Ertmer, 2016). In terms of science education, the results of preservice science teachers' TPACK level and development has been widely reported in extant studies, with less emphasis on how these ICTs are used in teaching and learning environment (Hsu, 2015; Yeh, Hsu, Wu, & Chien, 2017). In addition, studies revealed that science teachers may hesitate to use technology in their teaching due to low self-efficacy (Kazan & El-Daou, 2016; Joo, Park, & Lim, 2018; van Acker, van Buuren, Kreijns, & Vermeulen, 2013) or when technology does not contribute to meaningful learning (Joo et al., 2018).Therefore, there is a need for qualified science teachers who can integrate basic ICT software, hardware, and subject-specific emerging ICTs with sufficient content knowledge and contemporary pedagogical approaches, with the learning-teaching process. At this point, the transformative approach which defines TPACK as a unique knowledge rather than the intersection of the knowledge types comes to the front and there has been an increase in studies supporting the transformative approach (Jin, 2019; Kabakçı-Yurdakul et al., 2012; Yeh et al., 2014). Hence, this study is important in terms of presenting the relationship between ICT usage and TPACK of future science teachers in view of the transformative ICT-TPACK-Science framework. Also, with the empirical findings the present research provides opportunities to set the theoretical framework between ICT and TPACK dimensions to be verified in future research.

In the light of the literature, this study aims to investigate how accurately the linear combination of ICT measures can predict preservice science teachers' TPACK scores. This study was guided by the following research questions:

(1) Does preservice science teachers' ICT usage predict their TPACK scores?
(2) Does preservice science teachers' ICT usage predict their planning, designing, implementing, ethics, and proficiency scores?

2 Method

This method section includes five subtitles: research design, research context and participants, instruments, data analysis, and ethical issues and data collection procedure. First, the research design of the current study namely correlational research is explained. Second, the context that the study carried out and participants' profiles are described. Third, the properties of the instruments are explained. Forth, the data analysis approaches are described. Finally, the ethical principles employed to protect participants' rights and the procedures followed to collect data are given.

2.1 Research design

Correlational research as a type of quantitative research methodology was utilized with the purpose of prediction (Fraenkel et al., 2012). Accordingly, to what extent the ICT usage categories namely hardware, desktop software, and emerging ICTs explain preservice science teachers' TPACK scores was investigated. There was no manipulation of the studied variables. Three ICT usage categories were used to predict total TPACK scores as well as the scores obtained on each TPACK dimension.

2.2 Research context and participants

Teacher training programs are carried out under the Faculty of Education, and their curriculum is determined by the Council of Higher Education and employed on a national scale in Türkiye. Courses are grouped under three categories as teaching profession (e.g., Educational Psychology, Instructional Technologies), teaching methods in the subject area included both content area (e.g., Chemistry, Physics) and science teaching (e.g., Teaching Methods in Science Education, Science Teaching Laboratory Practices, Material Design in Science Education) courses, and general knowledge (e.g., History, Turkish Language, Information Technologies). Science teacher training programs are offered as a four-year (eight-semester) undergraduate program and each semester preservice science teachers took courses from each category. Courses offered in the third and fourth grades are required to integrate contemporary teaching approaches as well as educational technologies to science teaching. Since in these courses preservice science teachers develop their competencies in designing science teaching, they develop a more critical perspective in their profession. Therefore, the sixth and eighth-semester preservice science teachers were selected as the sample of the current study. The participants were selected using the convenience sampling technique from seven universities in different geographic regions of Türkiye. Totally 326 preservice science teachers (284 females, 42 males) participated. The age of participants ranged between 20 and 37 with a mean value of 21.62 ($SD = 1.41$) years.

2.3 Instruments

The data were collected using the ICT-TPACK-Science Scale and the ICT Usage Questionnaire.

ICT-TPACK-science scale. This scale was developed by the researchers to measure preservice science teachers' TPACK based on the transformative TPACK-ICT-Science framework (Kadıoğlu-Akbulut et al., 2020). It consists of 38 items under five dimensions namely planning ICT-integrated science instruction (planning), designing materials for ICT-integrated science instruction (designing), implementing ICT-integrated science instruction (implementing), ethics in ICT-integrated science instruction (ethics), and proficiency in ICT-integrated science instruction (proficiency). It is a five-point Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree).

The participants' total-TPACK scores were calculated by taking the mean of all 38 items. Additionally, factor scores were calculated by taking the mean of items under the related factor. Accordingly, the possible range of scores varied between 1 and 5. To calculate participants' TPACK levels under three categories as low, medium, and high, the difference between the highest and the lowest scores is divided into the number of levels (level = $(5-1)/3 = 1.33$). The evaluation criteria were determined by adding the 1.33 value found to the lowest possible value of 1.00. Consequently, the values between 1.00 and 2.33, 2.34 and 3.67, and 3.68 and 5.00 were accepted as low, medium, and high respectively.

For validity evidence for this current data set, Confirmatory Factor Analysis (CFA) was performed using LISREL (Jöreskog & Sörbom, 2004) to test how well the 38 items fit with the five-factor model. To evaluate model data fit the following crite-

Table 1 *The Number of Items, Sample Items, and the Cronbach Alpha Reliability Coefficients for the Dimensions of the ICT-TPACK-Science Scale*

Dimension	Number of items	Sample items	Reliability coefficients
Planning	8	I can determine appropriate instructional technologies and pedagogical approaches by evaluating student characteristics, duration, content, and attainment in the science teaching process.	0.87
Designing	6	In the process of science teaching, I can create/update visual materials using technologies such as MindMeister, Piktochart, Thinglink, Pixton etc. by the student characteristics, duration, content, and attainment.	0.82
Implementing	12	I can implement classroom management when using digital teaching materials (simulation, animation, etc.) in the science teaching process.	0.89
Ethics	6	I can adhere to the rights of intellectual property (royalties, licenses, etc.) when using technology at every stage of the science teaching process.	0.82
Proficiency	6	I can guide my colleagues in using technology to solve the problems encountered in the science teaching process.	0.87

ria were used. The $\chi 2$/df ratio below 2, Root Mean Square Error of Approximation (RMSEA) below 0.05, Comparative Fit Index (CFI) above 0.95 and Non-Normed Fit Index (NNFI) above 0.95 indicated a good fit (Browne & Cudeck, 1993; Jöreskog & Sörbom, 2004; Kline, 2011). When the error covariances between items 1 and 2, and items 25 and 26 were set free as suggested in the modification indices, the following fit indices were attained: $\chi 2 = 1026.53$ ($df = 653$, $p < .05$), RMSEA = 0.042, CFI = 0.99, and NNFI = 0.99, which showed a good model-data fit for the scale. The Cronbach alpha reliability coefficients for the dimensions ranged from 0.82 for the factors *designing and ethics* to 0.89 for the factor *implementing*, which pointed to highly reliable test scores. The number of items, sample items, and Cronbach alpha reliability coefficients for each dimension are given in Table 1.

ICT usage questionnaire. This instrument was developed by the researchers to measure preservice science teachers' knowledge about, and usage of ICT tools supportive in the field of science education. Initially, the items (ICTs) for the questionnaire were selected from the related literature according to relevance to science teaching (Bower, 2020; Goktas et al., 2009; Reyna et al., 2017). Next, the selected tools were classified under three categories as hardware, desktop software, and emerging ICTs considering the literature. The rating scale was written on a 4-point scale; 0 for “No idea”, 1 for “I know this technology, but I have never used it”, 2 for “I occasionally use it.”, and 3 for “I often use it.” Then, as for validity evidence, the form was sent to three experts who got their Ph.D. in educational technologies and had been teaching these technologies in the Science Education Teaching Program for many years. According to their suggestions, the final form of the questionnaire is composed of 30 tools involving commonly used ICTs in the field of science education considering the latest trends in educational technologies which remained listed under the predetermined three categories. These technologies include seven hardware, six desktop software and 17 emerging ICT tools (see Table 2). While calculating participants’ ICT usage scores on the hardware, desktop software, and emerging ICTs categories, their ratings on the tools defined under the related category were added up and they took zero points from the items that they had no idea about. The possible range of scores differed due to the altered number of tools under each category. Accordingly, the possible range of scores varied between 0.00 and 21.00, 0.00 and 18.00, and 0.00 and 51.00 for the hardware, desktop software, emerging ICTs categories respectively. Participants’ ICT usage levels as low, medium, and high were calculated similar to their TPACK levels. Since the possible lowest score that can be obtained from the questionnaire is zero, the maximum scores on each category were divided into three (see Table 2 for evaluation criteria). Finally, the Cronbach alpha coefficients were calculated for evidence of internal consistency. The alpha coefficients for the categories of hardware, desktop software, and emerging ICTs were 0.51, 0.71, and 0.84, respectively.

2.4 Data analysis

The following steps were followed while analyzing the data. Initially, the accuracy of the data file was checked and two cases responding to the TPACK scale but not on the ICT questionnaire were deleted. Next, the mean replacement procedure was safely employed to deal with the missing data, since the ratio of *missing data* was found to be below 5% and distributed randomly (Fraenkel et al., 2012). Then, descriptive statistics (mean, standard deviation, possible range, actual range, skewness, and kurtosis) were presented for the key measures. Additionally, bivariate correlations (Pearson correlations) among key measures were examined. Finally, six separate multiple regression analyses were conducted to test how well the ICT measures predicted preservice science teachers’ TPACK.

For all analyses, a stepwise regression method in which SPSS entered the variables according to a set of statistical criteria was used. The TPACK measures (total-TPACK, planning, designing, implementing, ethics, proficiency) were assigned as criterion (dependent) variables separately for each analysis and three ICT usage categories (hardware, desktop software and emerging ICTs) were used as predictors (independent variables) in all analyses. Before the analyses, the assumptions associated with multiple regression analysis were assessed thoughtfully: the ratio of

Table 2 *The Number and Name of Tools for ICT Knowledge Types*

ICT knowledge	Number of Tools	Level Limits	Name of Tools
Hardware	7	0.00–7.00 – Low 7.01-14.00 – Medium 14.01-21.00 – High	Computer, Scanner, Projector, Printer, Smartboard, Tablet, Smartphone
Desktop software	6	0.00–6.00 – Low 6.01–12.00 – Medium 12.01–18.00 – High	Spreadsheet (MS Excel etc.), Word processor (MS Word etc.), presentation (MS Powerpoint etc.), Desktop publishing (MS Publisher etc.), Image editing (Paint, Adobe Photoshop etc.), Graphic animation (Adobe Animate etc.)
Emerging ICTs	17	0.00–17.00 - Low 17.01–34.00 – Medium 34.01–51.00 – High	Cloud computing (Google Drive etc.), Social network (Facebook etc.), Wiki (Wikipedia), Podcast, Email, Instant messaging (WhatsApp, Google talk etc.), Learning management systems (Edmodo, Moodle, EasyClass etc.), E-books, Educational software (software Vitamin platform on the Ministry of National Education etc.), Alternative presentation tools (Prezi etc.), Video creation tools (Moviemaker, EdPuzzle, YouTube Editor etc.), Visual material design tools (MindMeister, Piktochart, Thinglink, Pixton etc.), Animation creation tools (Vyond, Powtoon etc.), Simulation creation tools (Algodoo etc.), Online exam tools (Socrative, Kahoot etc.), Augmented reality creation tools (Blippar etc.), Gamification tools (Classdojo etc.)

cases to independent variables; absence of outliers among the independent variables and on the dependent variable - univariate and multivariate outliers; absence of multicollinearity and singularity; normality, linearity, and homoscedasticity of residuals; independence of errors (Tabachnick & Fidell, 2014, 159–164). Four cases were deleted after analyzing the univariate and multivariate outliers' assumptions. As a result, 326 cases were left for regression analyses. While reporting the results of multiple regression analysis, two types of effect sizes—the degree of the multiple correlation (R^2 and adjusted R^2) and relative importance of independent (predictor) variables (β coefficients and sr^2) were interpreted.

2.5 Ethical issues and data collection procedure

The following ethical principles were followed to protect participants' rights. Initially, necessary permissions were taken from the Human Subjects Ethics Committee. Next, the preservice science teachers were informed about the aim of the study, possible benefits to participation, and confidentiality of the data, and how the data would be protected, participation was voluntary, and they could withdraw at any time. The data were gathered only from the participants who signed the informed consent form.

Since preservice science teachers mainly developed their science teaching competencies in the third and fourth grades, the data were collected from the sixth and eighth-semester students through the end of the semester. The forms and a guide for the data collection procedure were mailed to one conveniently accessible faculty member from each university and faculties themselves administered the informed consent forms and all the data collection instruments together after class hours. The data collection procedure was completed in approximately 30 min.

3 Results

3.1 Descriptive statistics

Frequencies, means, standard deviations, possible range, actual range, skewness, and kurtosis values as descriptive statistics for TPACK and ICT measures are presented in Table 3. The mean of the total-TPACK score was 3.84 (*SD*=0.47) and the means for the TPACK dimensions ranged from 3.19 to 4.17. Preservice science teachers reported the highest score at the *Ethics* dimension (*M*=4.17, *SD*=0.53) and the lowest at the *Designing* dimension (*M*=3.19, *SD*=0.74). As for ICT, the means for the ICT categories altered due to scoring and should be evaluated considering varying ranges. The skewness and kurtosis values for all measures suggested approximately normal distribution.

Table 3 *Means and Standard Deviations of Key Measures (N=326)*

				Range			
Measure	*n*	*M*	*SD*	*Possible*	*Actual*	*Skewness*	*Kurtosis*
Total-TPACK	326	3.84	0.47	1.00–5.00	2.46-5.00	0.001	−0.232
Planning	326	3.95	0.52	1.00–5.00	2.13-5.00	0.013	−0.065
Designing	326	3.19	0.74	1.00–5.00	1.00–5.00	−0.006	0.065
Implementing	326	4.11	0.51	1.00–5.00	2.58-5.00	−0.291	−0.137
Ethics	326	4.17	0.53	1.00–5.00	2.50-5.00	−0.302	−0.127
Proficiency	326	3.80	0.66	1.00–5.00	2.17-5.00	−0.100	−0.517
Hardware	326	15.15	2.35	0.00–21.00	7.00–21.00	−0.451	0.507
Desktop software	326	11.76	3.13	0.00–18.00	2.00–18.00	−0.189	0.046
Emerging ICTs	326	26.43	7.64	0.00–51.00	8.00–51.00	0.346	−0.007

Table 4 *Correlation Matrix for Key Measures (N=326)*

Measure	1	2	3	4	5	6	7	8	9
1.Planning	-								
2.Designing	. 414**	-							
3.Implementing	. 719**	0.444**	-						
4.Ethics	. 595**	0.326**	0.710**	-					
5.Proficiency	. 579**	0.465**	0.634**	0.559**	-				
6.Total-TPACK	. 809**	0.709**	0.858**	0.776**	0.824**	-			
7. Hardware	0.375**	0.206**	0.400**	0.327**	0.296**	0.394**	-		
8.Desktop software	0.416**	0.469**	0.461**	0.383**	0.374**	0.533**	0.515**	-	
9. Emerging ICTs	0.307**	0.547**	0.405**	0.282**	0.365**	0.496**	0.350**	0.564**	-

** p<.01 (two-tailed)

The correlation matrix for *Pearson product-moment correlation coefficients* for the TPACK and ICT measures is presented together in Table 4. All the correlations were found to be significant at the 0.01 level. The correlation coefficients of 0.10, 0.30, and 0.50, are interpreted as low, medium, and large coefficients, respectively (Green & Salkind, 2014). The magnitude of correlations among TPACK dimensions ranged from medium to high. While the highest correlation was found between planning and implementing dimensions (r=.719), the lowest correlation was found between the Designing and Ethics dimensions (r=.326). Furthermore, the correlations between ICT categories were also altered from medium to high. The highest correlation was observed between Desktop Software and Emerging ICTs categories (r=.564) and the lowest correlation was found between Hardware and Emerging ICTs categories (r=.350). Finally, the correlations among TPACK dimensions and ICT categories ranged from low to high. The highest correlation was observed between the designing dimension and emerging ICTs category (r=.547) and the lowest correlation was observed between the designing dimension and the hardware category (r=.206).

3.2 Inferential statistics

Six separate multiple regression analyses were conducted to evaluate how well the ICT measures predicted TPACK. The predictors were three ICT categories in all analyses, while one of the TPACK measures was used as the criterion variable in each analysis. The criterion variable, significant predictors, regression coefficients, zero-order correlations (r), and squared semi-partial (sr^2) correlations are given in Table 5. For the first analysis, the regression equation with three ICT measures as predictors was significantly related to the total-TPACK measure, R^2=0.355, adjusted R^2=0.349, F (3, 322)=58.975, p<.001. The *adjusted* R^2 value indicates that approximately a third of the variability in total-TPACK can be accounted for by the linear combination of three ICT measures. According to the standardized regression weights (β); the relative strength of the predictors changed in the following order: 0.307 for desktop software, 0.274 for emerging ICTs, and 0.140 for hardware. When the semi-partial correlations (sr^2) were evaluated, the sr^2 value of 0.053 for desktop software indicated that 5.3% of the variance in the total-TPACK was uniquely accounted for by desktop software, when emerging ICTs and hardware were controlled. Similarly, 5.1% of the variance in the total-TPACK was uniquely accounted for by emerging

Table 5 *Predicting TPACK Measures from ICT Knowledge Measures (N=326)*

			$CI_{95\%}$ for b				
Criterion	Predictors	b	Lower	Upper	β	r	sr^2
Total-TPACK	Desktop software	0.046	0.028	0.064	0.307	0.533	0.053
	Emerging ICTs	0.017	0.010	0.023	0.274	0.496	0.051
	Hardware	0.028	0.007	0.049	0.140	0.394	0.014
Designing	Emerging ICTs	0.040	0.030	0.050	0.415	0.547	0.118
	Desktop software	0.055	0.030	0.081	0.235	0.469	0.038
Implementing	Desktop software	0.040	0.020	0.060	0.245	0.461	0.034
	Hardware	0.044	0.021	0.068	0.206	0.400	0.031
	Emerging ICTs	0.013	0.005	0.021	0.195	0.405	0.026
Planning	Desktop software	0.051	0.032	0.070	0.303	0.416	0.068
	Hardware	0.049	0.024	0.074	0.219	0.375	0.035
Proficiency	Emerging ICTs	0.019	0.008	0.029	0.215	0.365	0.031
	Desktop software	0.040	0.012	0.068	0.188	0.374	0.020
	Hardware	0.035	0.002	0.068	0.124	0.296	0.011
Ethics	Desktop software	0.050	0.030	0.070	0.292	0.383	0.063
	Hardware	0.040	0.014	0.067	0.176	0.327	0.023

ICTs when other predictors were controlled. However, hardware uniquely contributed only 1.4% variance of the criterion variable.

The overall effect of the ICT predictors on the dimensions of the ICT-TPACK-Science Scale decreased in the following order: $R^2=0.337$, Adjusted $R^2=0.333$, $F(2, 323)=82.139$, $p<.001$ for Designing dimension; $R^2=0.274$, Adjusted $R^2=0.267$, $F(3, 322)=40.526$, $p<.001$ for Implementing dimension; $R^2=0.209$, Adjusted $R^2=0.204$, $F(2, 323)=42.553$, $p<.001$ for Planning dimension; $R^2=0.186$, Adjusted $R^2=0.178$, $F(3, 322)=24.474$, $p<.001$ for Proficiency dimension; and $R^2=0.170$, Adjusted $R^2=0.164$, $F(2, 323)=32.976$, $p<.001$ for Ethics. According to adjusted R^2 values 33.3% of the variability in Designing dimension can be accounted for by emerging ICTs and desktop software measures; 26.7% of the variability in Implementing dimension of can be accounted for by desktop software, hardware, and emerging ICT measures; 20.4% of the variability in Planning dimension can be accounted for by desktop software, hardware, and emerging ICTs, measures; 17.8% of the variability in Proficiency dimension can be accounted for by emerging ICTs, desktop software, and hardware measures; and 16.4% of the variability in Ethics dimension can be accounted for desktop software and hardware measures. When the relative effects of individual predictors were assessed, emerging ICTs made highest contribution to the Designing ($\beta=0.415$, $sr^2=0.118$) and Proficiency ($\beta=0.215$, $sr^2=0.031$) dimensions, and desktop software made highest contribution to the Implementing ($\beta=0.245$, $sr^2=0.034$), Planning ($\beta=0.303$, $sr^2=0.068$), and Ethics ($\beta=0.292$, $sr^2=0.063$) dimensions.

4 Discussion and conclusion

This study was conducted to reveal preservice science teachers' TPACK and predict the dimensions defined under the transformative ICT-TPACK-Science framework with ICT usage. The results of this study showed that preservice science teachers' TPACK was found to be at a high level. These findings are supported by the results of earlier studies conducted based on the transformative perspective that revealed a high level of TPACK for preservice science teachers (Atakan, 2019; Kabakçı-Yurdakul, 2011). Preservice science teachers also had high scores on all the dimensions except designing in which they obtained medium scores. The designing dimension specific to the ICT-TPACK-Science framework measures the material design using emerging ICTs. The relatively lower scores on the designing dimension indicated that preservice science teachers had difficulties in creating and updating materials by the student characteristics, duration, content, and course objectives using emerging ICTs in the process of science teaching. As indicated in studies (such as Dalacosta, Kamariotaki-Paparrigopoulou, Palyvos, & Spyrellis, 2009; Smetana & Bell, 2012; Webb & Cox, 2004), it is very important and helpful to use emerging ICTs in designing for an effective, efficient, and attractive science teaching process.

Considering ICT as a knowledge base for transformative TPACK similar to Angeli and Valanides (2009), in the present study preservice science teachers' ICT usage was determined according to the use of hardware, desktop software and emerging ICT tools. The results indicated that preservice science teachers' ICT usage for the hardware category was at a high level. Although preservice science teachers' mean ($M = 11.76$) for the desktop software was found at the medium level, the value was very close to the lower limit of high level which is 12.01. Finally, the emerging ICT usage category was found to be at the medium level. Higher-level ICT usage in these categories could be because of the continued use of these ICTs for both academic and daily purposes. On the other hand, lower-level ICT usage in the emerging ICT category might have been due to rapid changes in emerging ICT tools. These results are parallel to the findings of earlier studies which indicated that preservice science teachers are not frequently using emerging technologies (Sang et al., 2010; So & Kim, 2009; Tondeur, van Braak, Sang, Voogt, Fisser, & Ottenbreit-Leftwich, 2012). The reason of using ICTs less frequently may be due to lack of facilities, insufficient knowledge about ICTs and how to use them, low self-efficacy in using ICTs, etc.

There were low to high significant correlations among TPACK dimensions and ICT categories. In terms of hardware knowledge, the highest correlation was observed with the *implementing* dimension while the lowest correlation was observed with the *designing* dimension. This indicated that preservice science teachers who were competent at hardware knowledge were mostly using this knowledge while employing the technology-enhanced science teaching process. As for desktop software, the highest correlation was observed with the *designing* dimension while the lowest correlation with the *proficiency* dimension. Finally, for the emerging ICTs, the highest correlation was observed with the *designing* dimension and the lowest with the *ethical* dimension. Accordingly, preservice science teachers used desktop software and emerging ICTs frequently in the process of designing materials. On the other hand, the lowest correlation among TPACK dimensions and ICT categories was found between designing dimension and hardware category suggesting that preservice science teachers' knowledge of devices such as computers and interactive whiteboards does not necessarily increase their competencies in designing instructional materials using emerging ICT tools.

The conceptual relationship between ICT and TPACK dimensions in the ICT-TPACK-Science framework was tested through the regression models. The results revealed that the dimensions of ICT usage explain approximately one-third of the variability in TPACK can be accounted for by the linear combination of three ICT measures. However, the relative importance of the predictors was found to be closer and higher for the desktop software and emerging ICTs categories compared to the hardware category. Despite the higher value of the mean compared to other ICT categories, the hardware category made the lowest contribution to the regression model which was accepted as evidence for the transformative model. For effective and creative use of technology in science teaching, preservice science teachers are required to utilize desktop software and emerging ICTs and transform these ICTs considering pedagogy, content, learners, and context as suggested by Angeli and Valanides (2009). Similarly, Aktaş and Özmen (2022) found out that developing TPACK-based lesson plans using educational tools such as worksheets and simulations and using these materials in their teaching has a positive effect on preservice teachers' TPACK.

According to adjusted R^2 values, the overall effect of the ICT measures on the TPACK dimensions decreased in the following order: designing, implementing, planning, proficiency, and ethics. This indicated that preservice science teachers were employing ICT usage directly and more actively in the designing dimension in which they create/edit instructional materials using appropriate technologies in terms of student needs, teaching content, or learning environment. Among the five regression models for the TPACK dimension, emerging ICTs accounted for the highest variability in designing dimension which was one of the prominent findings of the present study. Likewise, Ocak and Baran (2019) mentioned that science topics are important in choosing the technologies used in the designing phase; for instance, for abstract topics more visualizations or for conceptualization aminations and simulations could be used. In addition, the researchers also expressed that when teachers are more confident in using technology, they are more likely to design their lessons with technological elements. The emerging ICTs might have promoted the development of TPACK in the designing dimension through the understanding of the added value of these tools in the transformation of particular topics considering the student characteristics, duration, content, and learning objectives. For example, while creating/updating visual materials using technologies such as MindMeister, Piktochart, Thinglink, Pixton, etc., preservice science teachers need to think about issues such as relevance to course objectives, students' learning difficulties, and appropriateness to student level.

Second, the contribution of three ICT measures to the model was very close to the implementation dimension. This implies that all three ICT usage categories are used in the process of science teaching with the help of technology. This finding is compatible with previous studies which expressed that the teachers usually prefer to use interactive whiteboards for teaching the science content (Ertmer et al., 2012; Ocak &

Baran, 2019) and during this implementation they use hardware, software and emerging ICTs while presenting the content.

Third, the planning dimension was explained through desktop software and hardware categories among which desktop software made a higher contribution. This indicates that the desktop software tools such as Word, PowerPoint, etc. supported the development of TPACK in the planning dimension when determining compatible instructional principles, methods, and instructional technologies. Fourth, among all three ICT measures emerging ICTs made the highest contribution to the model for the proficiency dimension which indicates that preservice science teachers good at in the emerging ICTs can produce alternative solutions by taking advantage of appropriate technologies for the problems encountered in science (a misconception, micro-macro notation, three-dimensional representation, connection with daily life, etc.) or guide others to the widespread use of these current technologies. Finally, the ethics dimension was explained through desktop software and hardware categories in decreasing order which suggests that preservice science teachers mostly consider the rights of intellectual property (royalties, licenses, etc.) and follow the ethical rules when using desktop software tools. In summary, emerging ICTs accounted for the highest variance in the designing and proficiency dimensions while desktop software made the highest contribution to the remaining dimensions.

4.1 Implications

The aim of the study was to examine the empirical data collected from the preservice science teachers and how preservice teachers' ICT usage reflects their TPACK. Findings revealed three ICT categories play role in pre-service teachers' TPACK. Moreover, three ICT categories were found to be of relatively varied importance levels for different TPACK dimensions. However, mean values for the preservice teachers' ICT categories were found to be a little above the midpoint of the possible scores. This might occur due to not familiarity with the ICT tools or not having opportunities for implementation. Desktop software (such as spreadsheet, word processor, presentation, etc.) and emerging ICTs (such as cloud computing, social network, learning management systems, visual material design tools, etc.) were mostly found to be significant predictors of TPACK, more practical implications should be conducted by preservice teachers to increase their experience in using ICT as well as integrating technology into the learning environment. Accordingly, preservice teachers need support to improve their knowledge of ICT tools and integrate ICTs into their science teaching considering the dynamic interactions of content, pedagogy, learners, and context knowledge bases which in turn results in higher TPACK. These empirical results could be also interpreted as provisional estimates to the theoretical framework considering ICT usage and TPACK dimensions. The future studies can use these priori orderings to reflect causal hypotheses. A stepwise regression method was used in this current study, but for the justification of the theoretical models between ICT and TPACK dimensions LISREL can be employed. Experienced in-service science teachers' technology integration can be also mapped out and the complex relations between their ICT usage and TPACK dimensions could be examined. Another implication for further research is to compare preservice and in-service teachers' ICT and

TPACK dimensions' models and the factors such as teaching experience, gender and competency of technology use could be also included into the models.

4.2 Limitations

The results of the current study should be evaluated considering its limitations. First, the main limitation of the study is that the study is based on self-reported data which is based on preservice science teachers' perceptions. Second, the technique used in this study was convenience sampling and to minimize its weakness the data were collected from seven universities from different regions of Türkiye. Third, it is limited to third and fourth-grade preservice science teachers. Fourth, the ICT usage defined under three categories was limited to the 30 ICT tools commonly used in science education considering the latest trends in educational technologies. Finally, the theoretical model was limited to the ICT-TPACK-Science framework based on a transformative approach.

5 Conclusion

In conclusion, the ICT-TPACK-Science framework involves the transformation of ICTs and their pedagogical affordances by the student characteristics, duration, content, and course objectives in the enriched science teaching process. At the center of this conceptualization is the view that technology is not simply a distribution tool that provides information, but a cognitive partner that enhances or improves student learning (Angeli & Valanides, 2009). Although this correlational study provided some insight into the complex relations between ICT and TPACK concepts, qualitative studies can also be conducted to understand how preservice science teachers utilize and transform a particular ICT tool in different TPACK dimensions for more effective science teaching. The results were specifically connected to the context of preservice science teachers. In further studies, these regression models could be tested with in-service science teachers. Moreover, the conceptualization of ICT-TPACK notions can be tested in different fields.

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Data Availability The data sets generated and analyzed during the current study are not publicly available due to anonymity issues but are available from the corresponding author upon reasonable request.

Declarations

Conflict of Interest None.

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Authors and Affiliations

Cansel Kadıoğlu-Akbulut[1] · Ayla Cetin-Dindar[2] · Burçin Acar-Şeşen[3] · Sevda Küçük[4]

✉ Ayla Cetin-Dindar
aylacetin@gmail.com

Cansel Kadıoğlu-Akbulut
canselkadioglu@gmail.com

Burçin Acar-Şeşen
bsesen@iuc.edu.tr

Sevda Küçük
sevdakucuk@atauni.edu.tr

[1] Department of Mathematics and Science Education, Tokat Gaziosmanpasa University, Tokat, Türkiye

[2] Department of Mathematics and Science Education, Bartin University, Bartin, Türkiye

[3] Department of Mathematics and Science Education, Istanbul University-Cerrahpasa, İstanbul, Türkiye

[4] Department of Computer Education and Instructional Technology, Ataturk University, Erzurum, Türkiye