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Investigating science and mathematics teacher candidate's perceptions of TPACK-21 based on 21st century skills

Bülent Başaran, *Dicle University,* Turkey, *basaranb@gmail.com* ORCID: 0000-0002-8850-5454

Abstract. Twenty-first century teachers are expected to have the ability to benefit from collaboration, problem solving, creative and innovative thinking, information and communication technology (ICT) applications. Teachers need to know various pedagogical approaches and appropriate ways to use ICT to support the development of twenty-first century skills of their students. The framework of technological pedagogical content knowledge (TPACK) provides a theoretical model for studying the way teachers use ICT in education. The purpose of this study is to reveal the relationships of the components that constitute the TPACK-21 scale. The data were collected from 254 teacher candidates at a state university in Turkey from the science and math departments in the academic year of 2017-2018. For this purpose, the relationships between the components/factors that constitute the TPACK-21 scale were examined with a model. Relational survey model was used in the research. In the research, the scale developed by Valtonen et al. (2017) determining prospective teachers' 21st century skills of TPACK-21 was used. The data obtained in the study were analyzed by structural equation modeling. The direct and positive effects of Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK21) and Pedagogical Content Knowledge (PCK21) from external variables consisting of binary knowledge fields of the research are seen on TPACK-21. These variables explain 74% of the change in TPACK-21. TCK is the variable that affects TPACK-21 the most. Another important result reached in this study is that teachers' content knowledge (CK) directly and positively affect TCK and PCK21 and this effect is greater than the effect of technological knowledge (TK) and pedagogical knowledge (PK21). When the results of this research are evaluated, a gradual model including CK and PCK21 can be proposed instead of a direct technology-based approach to professional development programs developed to increase 21st century competencies of teachers' TPACK-21s.

Keywords: 21st Century skills, TPACK, structural equation modeling, PLS-SEM, ICT

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INTRODUCTION

Teachers who choose to integrate 21st century technologies into their classes face a difficult task such as keeping up with rapidly changing technology and facing the seemingly never-ending re-learning technology cycle (Koehler & Mishra, 2008). This cycle offers teachers ways to learn to use new technological tools and to include them in their lessons. Web 2.0 tools such as Facebook, blog, wiki, podcast, video sharing sites and smartphones, smart boards, tablets, and cloud technologies have surrounded teachers of the 21st century from all directions. Although teachers think that these technologies may have a pedagogical value, they are still lacking in integrating these technologies into their lessons to organize their educational activities.

One of the challenges related to Information Communication Technologies (ICT) frameworks is the constant renewal of new technologies and tools. For this reason, it is argued that ICT competencies should not consist of certain technological skills since they will vary according to the used hardware and software (Tondeur, Van Braak & Valcke, 2007). Instead, more general competencies should be developed to teach and learn in technologies and subject areas. However, especially in the 21st century, developments in computer and internet technologies have revolutionized the life of mankind. Thus, as a result of increased human interaction with the computer and the internet, the knowledge and skills of using these technologies have become a basic necessity. This modern technology knowledge has a lot to add to the educational applications (Haddad & Draxler, 2002). It is stated that using the technology in the lessons improves the students' critical thinking ability (Jonassen, 2000), and increases the success (Lim & Chai, 2008), and increases satisfaction and active participation in the lessons (Fiksl, Flogie &

Abersek, 2017). ICT has unlimited usage potential in the real learning and teaching process. The world wide web, accessible from a web browser on mobile or computers, provides a wide range of unlimited information to teachers and students that can be accessed from anywhere at any time. Teachers can access online information that can help them in their lesson plans, improve the content of their lecture notes, learn new techniques and teaching methods, and update their knowledge of pedagogy subject content (Bhatti, Ahmad & Khan, 2014). At the same time, students can access useful information that can improve their understanding of the content of the subject they learn at school (Rosnaini & Arif, 2010). Online social media forums provide a platform for teachers and students to collaborate on teaching and learning at the local and international level; they provide environments for developing communication and discussions beyond the classroom among students and teachers. Moreover, using PowerPoint presentations and smart board technologies in the teaching and learning process will make it easier for teachers to convey the course contents to students (Serow & Callingham, 2008). If teachers use pictures, videos and documentaries on their presentations, they will make teaching easier and more tangible (Hammond & Manfra, 2009). In this way, effective and innovative use of 21st century technologies will help attract students' attention and will make the learning process more enjoyable in the classroom.

Teachers should support 21st century learning with this technology, prepare for new pedagogical approaches suitable for 21st century and understand how ICT and pedagogy interact to facilitate the development of 21st century qualifications in students. It has been widely accepted that prospective teachers should be prepared to integrate ICT in line with educational practices. The teacher training institutions are expected to provide the necessary competencies to teacher candidates to teach with ICT. Many teacher training institutions have started to open professional development programs that basically enable the development of ICT knowledge and skills to respond to these expectations (Polly, McGee & Sullivan, 2010). However, studies show that prospective teachers are often not prepared enough to effectively include technology in their classes (Ottenbreit-Leftwich, Glazewski, Newby & Ertmer, 2010). In the context of Turkey, prospective teachers do not want to integrate technology into teaching practices due to the insufficient technical facilities, insufficient educational opportunities to improve their experiences and lack of established learning application activities to guide them in their lessons (Başal, 2015; Merc, 2015; Kuru Gönen, 2019).

21st Century Learning Skills

The skills required for the 21st century have long been the subject of research to establish educational policy. The European Union has identified eight key areas for lifelong learning and the scope of each is defined. These are learning, communication, mathematics, scientific and technological competence, digital competence, cultural, social competences, initiative and entrepreneurship (Gordon et al., 2009). An international research center called "21st century skills assessment and teaching" defined 21st century skills as ways of thinking, ways of working, working tools and living in the world (Binkley et al., 2012). 21st century skills partnership, which is an institutional organization in the USA, has defined basic topics, 21st century themes, life and career, communication, collaboration, creativity, critical thinking and knowledge, media and technology skills (P21Skills, 2013).

The 21st century learning environment classified the 21st century skills to be successful in the current digital world as follows; learning and innovation skills (creativity, critical thinking, problem solving, communication and collaboration), information media and technology skills, life career skills (Applied Educational Systems, 2018). These are briefly explained:

Creativity: It enables students to review concepts from a different perspective that ultimately drives innovation.

Critical thinking: It is a skill that allows students to analyze the evidence and create judgment to solve problems.

Problem solving: It refers to the ability to solve problems effectively and timely.

Communication: It is a skill that enables students to exchange ideas effectively among their peers.

Collaboration: It means enabling students to work together to find a solution to a problem.
Information literacy: Understanding the facts, numbers, statistics and data.
Media literacy: Understanding the dissemination methods of information.
Technology literacy: Understanding the tools used to distribute information.
Life and Career skills: It enables lifelong learning by allowing personal and professional development.

The Framework of TPACK

In recent years, researchers have used the TPACK framework extensively to guide the design of teacher training programs (Mishra & Koehler, 2006). TPACK is considered an important framework for defining how well teachers can integrate technologies into their classes. The concept of TPACK emerged in learning technology based on pedagogical content knowledge (PCK) model with the leadership of Shulman (Voogt, Fisser, Roblin, Tondeur & van Braak, 2013; Chai, Hwee & Tsai, 2011b). TPACK is a complex knowledge of the interaction among technology, pedagogy and content (Chai, Koh & Tsai, 2013b). TPACK explained how teachers can facilitate learning specific content with a pedagogical approach and technology. Thanks to TPACK, it is also provided the ability to integrate 21st century qualifications into teaching. There are three important component knowledge that an educator should have; competencies in the subject's curriculum, pedagogy and technology, and specializing in accordance with these qualifications. These areas of expertise are also compatible with ICT's 21st century qualifications, which are prerequisites for teachers (Koh, Chai & Lim, 2017, Figg & Jaipal, 2012; Koehler et al., 2011).

Mishra and Koehler (2006) argue that in order for teachers to integrate ICT into their teaching, technological knowledge (TK), pedagogical knowledge (PK) and content knowledge (CK) must be synthesized to create TPACK. Mishra and Koehler (2006) assume that three other sources of knowledge can be obtained from interactions among TK, PK and CK: (a) Technological Content Knowledge (TCK); (b) Technological Pedagogical Knowledge (TPK); and (c) Shulman's (1986) pedagogical content knowledge (PCK). These seven structures express the professional expertise of different types of teachers needed for effective technology integration. Based on the previous literature (Cox & Graham, 2009, Mishra & Koehler, 2006), the seven structures are briefly explained below:

1) Technological knowledge (TK): Teachers' ability to use this technology efficiently in the classroom, knowing the possibilities or limitations of a particular technology. (For example: Drawing a mathematical shape using the math software GeoGebra).

2) Content knowledge (CK): Knowledge of the subject taught to students, for example; Turkish, mathematics, physics, (eg theoretical knowledge on GeoGebra software).

3) Pedagogical knowledge (PK): Knowledge related to teaching methods, lesson planning, assessment and general classroom management skills. (For example: When teaching GeoGebra software, it consists of knowing which teaching strategy and method knowledge to use and where students may encounter learning difficulties and evaluating it.)

4) Pedagogical content knowledge (PCK): Knowledge on how to teach students specific content-based materials. (For example, when describing the GeoGebra software, being able to transform the content knowledge related to the subject into the way that the students can understand best. Knowing the place and importance of GeoGebra in learning geometry and the expected achievements of the students).

5) Technological content knowledge (TCK): Knowledge on how to choose and use different technologies to transmit specific content knowledge. (For example; using the GeoGebra software, subjecting mathematical applications, drawing shapes, etc.).

6) Technological pedagogical knowledge (TPK): Knowledge of using technology to apply different teaching methods. (For example; when using GeoGebra software, asking students to share their thoughts, asking different solutions, directing their drawings, etc.)

7) TPACK: Knowledge of using technology to apply teaching methods for different types of subject content (Koehler & Mishra, 2009). (For example; when using GeoGebra software, knowing the appropriate pedagogical techniques and knowledge according to the level of the students,

knowing how to help and affect the students). The diagram showing TPACK and knowledge types are shown in Figure 1.

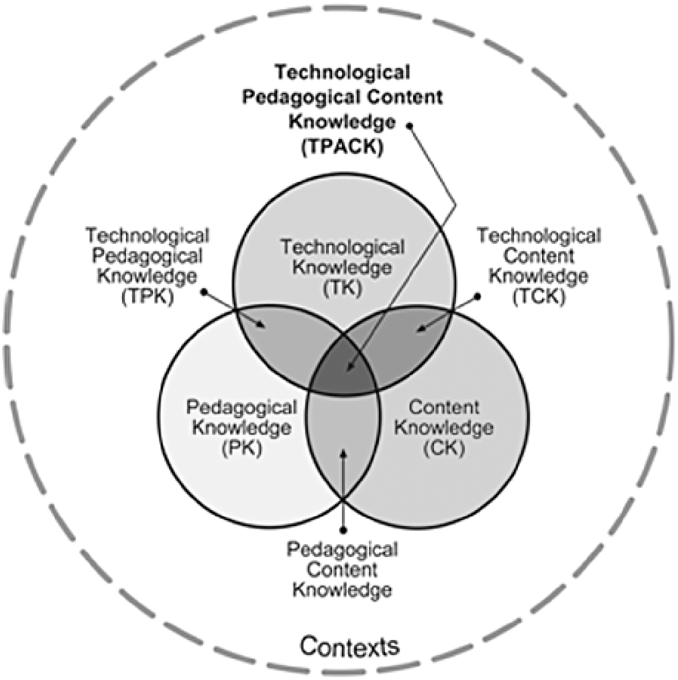

FIGURE 1. *TPACK and knowledge types (Koehler & Mishra, 2009)*

The TPACK framework can be used to implement ICT. The TPACK framework is a reference for the use of technology in learning, which demonstrates the relationship among TK, PK and CK for three key areas of knowledge that the teacher should have. In order to maximize the use of ICT in learning activities, the most important thing to consider is that teachers can implement ICT correctly.

TPACK can also be used as a main reference for teachers in developing self-efficacy and learning innovations. In addition, the expectation of being a professional teacher who can integrate ICT and technology can overcome the learning problem of students, thus making it easier to understand the materials included in the curriculum. TPACK's main concept emphasizes the relationship among subject, technology and pedagogy (Pamuk, Ergun, Cakir, Yilmaz & Ayas, 2015). The interaction among the three components has the power and attractiveness to encourage students to active learning focused on learning.

Although there are TPACK studies on science and mathematics education in the literature, these are basically experimental or limited number of qualitative studies that examine teachers or prospective teachers' TPACK 21st century skills of teaching a unit or subject. In this study, it is aimed to reveal the relationship between prospective teachers' TPACK-21st century qualifications and sub-dimensions in a state university at the department of science and mathematics (science, mathematics, physics, chemistry) in Turkey. It is emphasized in the literature that the relationship among the sources of knowledge that constitute the TPACK theoretical framework is still uncertain (Chai, Ng, Li, Hong & Koh, 2013a).

The aim of the study

The aim of this study is to reveal the perceptions of prospective teachers studying in science and mathematics departments in Turkey related to the relationship among the TPACK 21st century qualifications scale and its sub-dimensions.

To achieve this goal, the relationships among the components of the TPACK 21st century qualifications scale were examined by structural equation modeling.

In this study, the following questions will be answered:

1- Which variables affect the perceptions of prospective teachers studying in science and mathematics departments towards TCK and how much do these variables explain TCK?

2- Which variables affect the perceptions of prospective teachers studying in science and mathematics departments towards TPK21 and how much do these variables explain TPK21?

3- Which variables affect the perceptions of prospective teachers studying in science and mathematics departments towards PCK21 and how much do these variables explain PCK21?

4- Which variables affect the perceptions of prospective teachers studying in science and mathematics departments towards TPACK21 and how much do these variables explain TPACK21?

METHODS

Research Pattern

Relational survey model was used in this research. With the relational survey model, it is aimed to determine the relationship between two or more variables and to obtain clues about cause and effect (Büyüköztürk, Akgün, Demirel, Karadeniz & Çakmak, 2015). The variables of this study consist of the factors of CK, PK21, TK, TCK, PCK21, TPK21 and TPACK21, which are the sub-dimensions of the 21st century scale of TPACK.

The Population and Sample

This research was carried out with 254 prospective teachers studying at a state university in Turkey at the department of mathematics and science education (Mathematics, Physics, Chemistry, Biology and Science Departments) in the academic year of 2017-2018.

Data Collection Tools

In this research, TPACK-21 scale developed by Valtonen, Sointu, Kukkonen, Kontkanen, Lambert, and Mäkitalo-Siegl (2017) was used as data collection tool. First, written permission was obtained from the first author of the article, Teemu Valtonen. Later, studies were started with the permission of the university ethics committee. The scale consists of 38 items and seven sub-dimensions. Firstly, it was translated from English to Turkish by the researchers for the adaptation study of the scale. Afterwards, a specialist evaluation form was distributed to 2 lecturers in the foreign language department and asked to evaluate the compatibility of the English-Turkish translated scale form. Later, Turkish language validity and meaning integrity of the scale were reevaluated by a Turkish language expert. Translating the necessary items to make the scale items meaningful in the translated language and formatting them according to social and individual norms constitute the basis for adapting the scale to a new culture (Aksayan & Gözüm, 2002; Öner, 1987). The Turkish form of the scale was completed by making the necessary arrangements in line with the expert opinions. The prepared Turkish form was applied after informing the students in the study group about the purpose of the study. The survey focuses on TPACK from nine perspectives: Pedagogical knowledge (seven items such as “facilitating students' discussion in group work (2-5), facilitating students' reflective thinking”); Technological competence (“I'm familiar with new technologies and features”); Content knowledge in science (four items such as “I understand the basic theories and concepts of science”); Technological pedagogical knowledge (three items such as “I can choose the best possible technological methods for science teaching”); Technological pedagogical knowledge 21 (three items such as “I know how to use ICT in teaching as a tool for sharing ideas and thinking together”); Pedagogical content knowledge (three items such as “I can choose the best possible methods for science teaching”); Pedagogical content knowledge 21 (three items such as “when teaching science, I know how to guide students to improve their problem solving skills in the groups of 2-5 people”); Technological content knowledge (four items such as“ I understand ICT practices used by experts in science”) and TPACK (seven items such as “I know how to use information technologies in science as a tool for sharing and thinking together”). TPACK-21 scale in total: pedagogical knowledge (PK21; 7 items), content knowledge (CK; 4 items), technology knowledge (TK; 4 items), pedagogical content knowledge (PCK21; 6 items), technological pedagogical knowledge (TPK21; 6 items), technological content knowledge (TCK; 4 items) and technological pedagogical content knowledge (TPACK21; 7 items). PK21, TPK21, PCK21 and TPACK21 match the skills of the twenty-first century. Participants' opinions about TPACK-21 areas were evaluated using a 6-grade Likert type scale (rated from "1= I need additional knowledge about the subject" and "6= I have strong knowledge about the subject"). Cronbach alpha values related to the reliability of the scale; PK21 ($\alpha = .93$), CK ($\alpha = .92$), TK ($\alpha = .88$), PCK21 ($\alpha = .95$), TPK21 ($\alpha = .95$), TCK ($\alpha = .89$) and TPACK21 ($\alpha = .96$).

Data Analysis

In this study, structural equation modeling (SEM) was used to analyze the data. SEM is a statistical approach used to test causal and mutual relationships between hidden and observed variables to test a theoretical model (Schumacker & Lomax, 2004). Linear relationships between hidden and observed variables can be tested with hypothesis models (Harring, Weiss & Li, 2015). There are two techniques in SEM, the first is the Partial Least Squares (PLS) method, and the second is the covariance-based (CT) technique (Hair, Hult, Ringle & Sarstedt, 2014). PLS is a more appropriate approach for causal research that allows exploratory research. CT is the most suitable technique to test more established theories (Nejati, Rabiei & Chiappetta Jabbour, 2017).

The popularity of the PLS-SEM technique is due to the fact that it does not require large samples to analyze the data (Kuei, Madu, Chow & Chen, 2015, Laguir, Stagliano & Elbaz, 2015). However, it does not need to provide normal distribution assumptions. Model estimates provided by this technique are very correct (Hair et al., 2014). The path coefficient presented by PLS-SEM represents the strength of the relationship between the analyzed structures (Hwang, Jeong & Ban, 2016). PLS-SEM aims to maximize the explained variance of dependent hidden structures (Gallardo-Vázquez & Sanchez-Hernandez, 2014).

In this study, the predictive relationships of prospective teachers studying in science and mathematics departments related to TK, PK21, CK, PCK21, TCK, TPK21, TPACK21 were analyzed by using the SmartPLS 3 program according to SEM using the partial least squares technique.

RESULTS

SEM was applied to determine the relationship among the variables of the study; TK, PK21, CK, PCK21, TCK, TPK21 and TPACK21. The structural equation model tested in the study includes six external variables (TK, PK21, CK, PCK21, TCK, TPK21) and an endogenous variable (TPACK21). The internal and external model of the structural equation model in the study is shown in Figure 2.

Model Fit

The main purpose of the model design is to create the internal (structure) model and the external (measurement) model. The inner model shows the relationships between the structures, while the outer model presents the relationships between the indicators and the structures. Hair, Hult, Ringle and Sarstedt (2017) show that the first step in PLS-SEM is to create a path model that connects variables to structures. Figure 1 shows the internal and external model of this study.

The first value to check is "Indicator Reliability". All indicators should have indicator reliability values greater than the minimum acceptable level of 0.4 and close to the preferred level of 0.7 (Hulland, 1999). In the study, all indicator reliability is above the acceptable minimum level of 0.4 (Table 1).

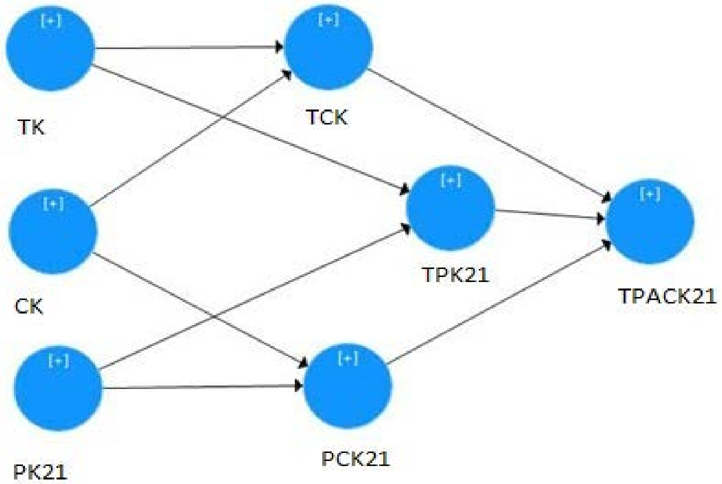

FIGURE 2. *Internal and external model of the study*

Traditionally, "Cronbach's alpha" value is used to measure internal consistency reliability in social science researches. The expected reliability coefficient for data tools that can be used in the research is 0.70 or above (Anastasi, 1982; Tezbaşaran, 1997). It is seen that the reliability level for TPACK-21 scale is high (Table 1).

Composite Reliability value should be 0.7 or higher. But for an exploratory research, a value of 0.6 or higher can also be accepted (Bagozzi & Yi, 1988). It can be seen from Table 1 that these values are greater than 0.7, so there is a high level of internal consistency reliability among all seven reflective latent variables.

Average Variance Extracted (AVE) of each latent variable is evaluated to check its convergent validity. This value should be 0.5 or higher (Bagozzi & Yi, 1988). In Table 1, again, it is seen that all AVE values are much higher than the acceptable level of 0.5, therefore the validity and reliability of the model has been confirmed.

Table 1. *Results summary for reflective external models*

Latent Variable	Indicators	Loadings	Indicator Reliability (i.e., loadings²)	Composite Reliability	Cronbach's Alpha	Average Variance Extracted (AVE)
TK	TK1	0,815	0,664	0,922	0,887	0,749
	TK2	0,929	0,863			
	TK3	0,894	0,799			
	TK4	0,819	0,671			
CK	CK1	0,800	0,640	0,905	0,860	0,704
	CK2	0,870	0,757			
	CK3	0,861	0,741			
	CK4	0,822	0,676			
PK21	PK1	0,706	0,498	0,907	0,881	0,583
	PK2	0,749	0,561			
	PK3	0,815	0,664			
	PK4	0,735	0,540			
	PK5	0,788	0,621			
	PK6	0,791	0,626			
	PK8	0,755	0,570			

TCK	TCK1	0,807	0,651	0,909	0,866	0,713
	TCK2	0,873	0,762			
	TCK3	0,853	0,728			
	TCK4	0,844	0,712			
TPK21	TPK1	0,820	0,672	0,922	0,898	0,664
	TPK2	0,837	0,701			
	TPK3	0,803	0,645			
	TPK4	0,839	0,704			
	TPK5	0,805	0,648			
	TPK6	0,783	0,613			
PCK21	PCK1	0,755	0,570	0,924	0,900	0,668
	PCK2	0,828	0,686			
	PCK3	0,852	0,726			
	PCK4	0,839	0,704			
	PCK5	0,821	0,674			
	PCK6	0,807	0,651			
TPACK21	TPACK1	0,840	0,706	0,940	0,926	0,692
	TPACK2	0,805	0,648			
	TPACK3	0,766	0,587			
	TPACK4	0,835	0,697			
	TPACK5	0,882	0,778			
	TPACK6	0,841	0,707			
	TPACK7	0,849	0,721			

Fornell and Larcker (1981) stated that if the square root of AVE in each latent variable is larger than other correlation values among latent variables it can be used to provide distinctive validity (Table 2)

Table 2. *Distinctive validity*

	CK	PCK21	PK21	TCK	TK	TPACK21	TPK21
CK	**0.839**						
PCK21	0.646	**0.818**					
PK21	0.427	0.602	**0.763**				
TCK	0.581	0.491	0.343	**0.845**			
TK	0.514	0.408	0.321	0.544	**0.865**		
TPACK21	0.591	0.658	0.469	0.766	0.581	**0.832**	
TPK21	0.555	0.623	0.554	0.720	0.632	0.791	**0.815**

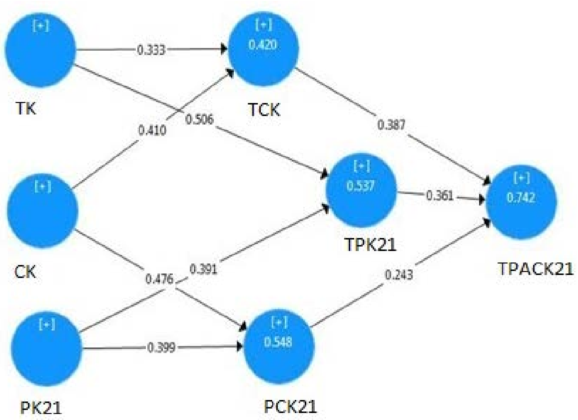

FIGURE 3. *Structural model with path coefficient values*

Figure 3 shows the path coefficients of the structural model. After determining the reliability and validity of the measurement model, the structural model is evaluated. The coefficient of determination and effect size are measured to evaluate the structural model. In addition, it is analyzed whether the predicted hypotheses are supported by path coefficients (Hair et al., 2017). In the following sections, more detailed information about valuation of the internal model is given (Table 3).

Coefficient determination (R^2) is a statistical measure of how close the data is to the appropriate regression line. It is also known as the determination coefficient or multiple determination coefficient for multiple regression. R^2 can take any value between 0 and 1. A value closer to 1 indicates that it is explained with a larger variance by the model.

Table 3. *Determination coefficients*

	R Square
PCK21	0.548
TCK	0.420
TPACK21	0.742
TPK21	0.537

Table 4 shows the path coefficient and p-values for the hypotheses of questions 1, 2, 3 and 4 in the study. Path coefficient provides the importance of hypothetical relationships that connect structures.

Table 4. *Path coefficients and p-values*

	Path Coefficients	T-value	Significance level
CK -> PCK21	0.476	9.217	0.000
CK -> TCK	0.410	6.324	0.000
PCK21 -> TPACK21	0.243	5.262	0.000
PK21 -> PCK21	0.399	7.686	0.000
PK21 -> TPK21	0.391	8.011	0.000
TCK-> TPACK21	0.387	6.777	0.000
TK -> TCK	0.333	4.702	0.000
TK -> TPK21	0.506	10.463	0.000
TPK21 -> TPACK21	0.361	5.769	0.000

In Table 4, according to the first question sentence, TK ($\beta = 0.333$) and CK ($\beta = 0.410$) are positive and directly affect TCK, and TCK explains 42% of the variance. In addition, in the analysis made according to the second question sentence, TPK21 was explained with a ratio of 54% with TK ($\beta = 0{,}506$) and PK21 ($\beta = 0{,}391$). Similarly, in the third question sentence, CK ($\beta = 0.526$) and PK ($\beta = 0.399$) positively and directly affect PCK21 and explain 55% of the change in PCK21. In the fourth question sentence, other external variables of the study consisting of binary knowledge fields TCK ($\beta = 0{,}387$), TPK21 ($\beta = 0{,}361$) and PCK21 ($\beta = 0{,}243$) have direct and positive effects on TPACK21. These variables make up 74% of the change in TPACK21. TCK is the variable that affects TPACK21 the most. According to this finding, TCK is critical in the technology integration of teachers. TPK21 is the second variable that has the biggest impact on teachers' 21st century competencies perceptions of TPACK21 after TCK. These two findings reveal that prospective teachers' ability to integrate pedagogical knowledge, content knowledge and technological knowledge affects TPACK-21 21st century competencies perceptions. PCK21 ($\beta = 0.24$) is less effective on TPACK21 21st century competencies than the other two dimensions.

DISCUSSION and CONCLUSIONS

The aim of this study is to determine the levels of TPACK-21 twenty-first century competencies levels of the prospective teachers studying in the science and mathematics departments and the relationships among the TPACK-21 scale and its sub-dimensions. For this purpose, the data were collected from 254 students studying at the departments of science and mathematics in a state university in Turkey. As a result of the analysis of the data, a model that explains the TPACK-21 at the level of 74% was created. In this model, TK and CK directly and positively affect TCK. The findings of this study show that the positive and direct effect of TK and CK on TCK and these two types of knowledge also increase teachers' TCK. However, studies indicate that having sufficient knowledge independently in these two areas is not sufficient for TCK, and the integration of these two areas should be taught specifically (Cengiz, 2013). The fact that the effect of CK on TCK is higher than that of TK in this research model may mean that prospective teachers have sufficient knowledge about the basic theories of science and mathematics. Content knowledge is defined as the knowledge of teachers about the subject / content learned or taught. Teachers should understand the nature of knowledge and find differences among each basic knowledge to provide information that the student can easily understand. It shows that the content knowledge of science and mathematics teacher candidates is more effective than technological knowledge in the integration of these two sub-dimensions. In their study, Valtonen et al. (2017) stated that prospective teachers were the weakest in the field of TK. Researchers believe that teachers' TCs are very important and their confidence in this area can help them develop their confidence in other knowledge areas later (Graham et al., 2009). Technological knowledge is undoubtedly one of the foundations of ICT integration, and research has shown that upgrading teachers' technological skills increases the likelihood of using ICT in the classroom (Hammond, Reynolds & Ingram, 2011). In some studies in the literature, teachers who consider themselves sufficient in terms of content knowledge show that they are more successful in choosing the appropriate technology for the subject they teach (Akarsu & Güven, 2014; Chai, et al., 2013b; Chai, Koh & Tsai, 2010; Chai, et al., 2011a).

PK21 and TK directly and positively affect teachers' perceptions of TPK21 twenty-first century competencies. Pedagogical knowledge is the knowledge of processes and practices, or teaching and learning methods to achieve educational goals (Mishra & Koehler, 2006). In the PK21 sub-dimension, 4 expressions are composed of special components that discuss the 21st century, showing that prospective teachers can apply learning strategies in accordance with 21st century skills. These skills need to be integrated into the teaching and learning process in the field of education as a learning tool and purpose. Technological knowledge is defined as technological knowledge that can be used to support learning; and teacher's knowledge about technology is one of the basic aspects of TPACK model (Jordan, 2011). According to this finding, the increase in the scores of science and mathematics teacher candidates in PK21 and TK sub-dimensions causes an increase in the knowledge of teachers to use technology for pedagogical purposes in the teaching process. Guzey and Roehrig (2009) stated that TK and PK affect each other positively. The fact that TK's effect on TPK21 is higher than PK21 in this study means that prospective teachers have gained the expected 21st century skills and teachers have the ability to guide students by using various pedagogical and ICT approaches to support the development of 21st century skills. In another study, teachers' TPACK competencies were examined after an in-service training on information and communication technologies. In line with the findings of that study, the strongest correlation among teachers' TPACK sub-dimensions was found to be between TK and TPK (Chai et al. 2011a; Lehiste, 2015). In their studies using the structural equation model, Günbatar, Damar and Boz (2017) stated that the most basic knowledge contributing to the TPACK development of 665 senior science teachers who study at the education faculties of seven different universities is PK.

PK21 and CK of science and math teachers have a direct and high impact on PCK21 competencies. These findings contradict previous studies such as Mtebe, Mbwilo and Kissaka (2016), who found that most of the teacher candidates had low content knowledge and pedagogical knowledge, especially in science and mathematics. A possible explanation for this finding is thought to be a significant improvement in the quality of teacher training programs at prospective teachers' universities. As stated by Shulman (1986), teaching is a profession that requires the use of content knowledge and pedagogical knowledge together. Therefore, the integration of these two areas is a necessary condition for the teaching profession according to Shulman (1986). This research also defines the knowledge of PCK specified for teaching by Shulman (1986) as choosing learning methods, approaches, models in content teaching to create a better education (Mishra & Koehler, 2006). PCK plays an important role in providing teachers with thinking strategies, teaching tips and tricks, and encouraging them to discover the understanding of practice by establishing a better relationship between learning objectives and the learning process (Loughran, Milroy, Berry Gunstone & Mulhall, 2001). In their study, Valtonen et al. (2017) achieved a high correlation between PK21, CK and PCK. Therefore, the development of science and mathematics teacher candidates' knowledge in these two fields and the integration of these two fields are important for the teaching profession (LeBlanc, Cavlazoglu, Scogin & Stuessy, 2017; Riandi, Apriliana & Purwianingsih, 2018). In some studies in the literature, it is stated that the lack of theoretical knowledge about the subject taught by teachers causes misconceptions of students, different representations of the subject and the selection of inappropriate metaphors (Tondeur, Scherer, Siddiq, & Baran, 2017). Canbazoğlu, Demirelli and Kavak (2010) pointed out that the teachers' lack of conceptual knowledge about the content they teach prevents students from choosing different teaching methods while teaching the concepts. Therefore, competence in content knowledge directly affects teachers' PCK.

According to another finding obtained in the research, TPK21, TCK and PCK21 of science teachers affect TPACK-21 directly and positively. The highest level of trust is seen in the TCK dimension. Valtonen et al. (2017), Harris and Hofer (2011) concluded that TPK, TCK and PCK competencies increased directly in proportion with TPACK competencies in their studies demonstrating the importance of activity based TPACK training. Cengiz, (2013) stated that teachers have difficulties in classroom applications because in-service trainings on technology are based on theoretical knowledge and technological tools are taught independently from the subject area. Emphasizing the importance of developing TPK, TCK and PCK for effective technology integration, researchers emphasize that training programs should be implemented where technology, teaching methods and subject areas interact (Canbazoğlu Bilici & Baran, 2015; Harris & Hofer, 2011). However, providing in-class technological equipment, facilitating teachers' access to technology and increasing their attitudes towards technology will not guarantee the integration of technology into the teaching process (Perkmen & Tezci, 2011). In their study conducted with 563 science teachers, representing Turkey's science teachers working in the 81 provinces, Kıray, Çelik and Çolakoğlu (2018) stated that PCK is the most influential variable compared to TPK and TCK and it has a critical role in technology integration.

In this study, it was determined that the effect of content knowledge (CK) on TCK, which is the sub-dimension of TPACK-21, is more than technological knowledge, and similarly, the effect of content knowledge (CK) on PCK21 dimension is higher than pedagogy (PK21). It seems that prospective teachers have more confidence in integrating science and mathematics knowledge, technology and pedagogy into this content knowledge. This reveals that content knowledge that is in the shadow of pedagogical and technological competencies in the field of education should be reviewed. The findings of this study show that prospective teachers with sufficient content knowledge have more confidence to integrate both technological knowledge and pedagogical knowledge into this content knowledge. In other words, when technology-oriented education is given instead of education by including technology in content knowledge, teachers' self-efficacy on content knowledge is expected to increase, otherwise negative results are obtained. Appleton, (1995) found that when prospective teachers had more self-confidence in science teaching and learning, their knowledge of science discipline also increased and their ability to access science and technology content was higher. Previous studies in the field of PCK have emphasized the importance of content knowledge in developing teachers' PCK (van Driel, Verloop and de Vos 1998; McCrory 2008). Van Driel, Verloop and de Vos (1998), emphasized that prospective teachers should improve their own content knowledge before developing their PCK. Those who previously discussed content knowledge as a separate dimension of knowledge decided on the idea that subject knowledge is very important for PCK (Kind 2015). Similarly, at the end of the three-week TPACK course, Ansyari (2012) stated that teachers' self-efficacy in content knowledge (CK) did not change, and there was an increase in other dimensions of TPACK. Kleickmann et al. (2013), in their study, concluded that the increase in CK also increases PCK. Irmak and Tüzün (2019), on the other hand, found that content knowledge related to genetics does not make an important contribution to PCK in their studies with prospective science teachers.

Another important finding obtained from the model in this study is that the TCK is the type of knowledge that affects the TPACK21 of prospective science and mathematics teachers. Teachers should know not only the subject they teach, but also how the subject can be changed with technology applications (Schmidt, Baran, Thompson, Mishra, Koehler & Shin, 2009). According to this result, it can be said that technology content knowledge is an integral part of technology integration into education. In other words, prospective teachers who do not know how to use technologies that use the concepts of science and mathematics in the best way will not be able to adequately integrate technology into the teaching process, no matter how much knowledge they have.

For this reason, the technology should not be made as an add-on to existing curricula of teacher training institutions, but the main curriculum, which takes into account these new advances and changes, must be reconstructed. Prospective teachers need to learn how to use ICT to help their students learn 21st century competencies in the future (Lambert & Cuper, 2009).

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