Kuramsal Eğitimbilim Dergisi, 11(2), 296-317, Nisan 2018
Journal of Theoretical Educational Science, 11(2), 296-317, April 2018
[Online]: http://dergipark.gov.tr/akukeg
DOI number: http://dx.doi.org/10.30831/akukeg.368836

Teknolojik Pedagojik Alan Bilgisi Modelinin İlkokul Matematik Öğretimine Uygulanması: Ölçek Uyarlama Çalışması*

Application of Technological Pedagogical Content Knowledge Framework to Elementary Mathematics Teaching: A Scale Adaptation Study

Mehmet Hayri SARI** **Ali BOSTANCIOĞLU*****

Received: 19 December 2017 **Accepted:** 22 February 2018

ABSTRACT: The present study aimed to adapt the Technological Pedagogical and Content Knowledge (TPACK) for mathematics teaching questionnaire into Turkish for classroom teachers who work in public schools. There were three stages in the questionnaire adaptation process. The questionnaire's language validity was established in the first stage, validity in the second and reliability in the third stage. Exploratory Factor Analysis (EFA, *n*= 372) and Confirmatory Factor Analysis (CFA, *n*= 310) have been utilized in establishing the validity of the questionnaire. A four-factor solution emerged as a result of EFA: 1) Knowledge of Teaching Mathematics with Technology (KTMT); 2) Knowledge of Teaching Mathematics (KTM); 3) Content Knowledge for Mathematics (CKM); and 4) Technology Knowledge (TK). Those four factors explained 62.20 % of the total variation in the questionnaire. In addition, the results of CFA suggested a good model fit and the internal consistency (α) for the whole questionnaire was calculated as .97. Total item correlation coefficients of all items were higher than .30. Evaluation of these results suggests that a valid and reliable Technological Pedagogical Content Knowledge questionnaire, which consists of 47 items under four subscales (KTMT, KTM, CKM, and TK), was developed.

Keywords: technological pedagogical and content knowledge, TPACK, technology, primary mathematics, primary school teacher.

ÖZ: Bu çalışma ile devlet okullarında görev yapmakta olan sınıf öğretmenlerine yönelik matematik öğretiminde teknolojik pedagojik alan bilgisi ölçeğinin Türkçeye uyarlanması amaçlanmıştır. Araştırmada ölçek uyarlama çalışması üç aşamada gerçekleştirilmiştir. Birinci aşamada ölçeğin dil geçerliliği, ikinci aşamada ölçeğin geçerliliği ve son aşamada ise ölçeğin güvenilirliği sağlanmıştır. Geçerlik çalışması kapsamında açımlayıcı faktör analizi (AFA, *n*= 372) ve doğrulayıcı faktör analizi (DFA, *n*= 310) yapılmıştır. AFA sonucunda ölçek 4 faktörlü bir yapı sergilemiştir: 1) Teknoloji ile Matematik Öğretimi Bilgisi (TMÖB), 2) Matematik Öğretimi Bilgisi (MÖB), 3) Matematik Alan Bilgisi (MAB) ve 4) Teknoloji Bilgisi (TB). Ölçekte yer alan bu 4 faktör ise; tüm ölçekteki maddelerin % 62.20'sini açıklamaktadır. DFA sonuçları elde edilen modelin geçerliliğinin iyi olduğunu göstermiştir ve ölçeğin iç tutarlılığı (α) .97 olarak hesaplanmıştır. Madde toplam korelâsyonu katsayılarının ise .30'dan büyük olduğu bulunmuştur. Tüm bu elde edilen veriler değerlendirildiğinde ilkokul matematiğine yönelik 47 maddelik ve dört alt boyuttan (TMÖB, MÖB, MAB ve TB) oluşan güvenilir ve geçerli bir ölçek elde edilmiştir.

Anahtar kelimeler: teknolojik pedagojik alan bilgisi, TPAB, teknoloji, ilkokul matematik, sınıf öğretmeni.

* An earlier version of this paper has been presented in International Teacher Education and Accreditation Congress organized by Yıldız Teknik University on May, 19-21, 2017.
** *Corresponding Author:* Asst. Prof. Dr., Nevsehir Haci Bektas Veli University, Nevşehir, Turkey, mhsari@nevsehir.edu.tr
*** Dr., Nevsehir Haci Bektas Veli University, Nevşehir, Turkey, abostancioglu@nevsehir.edu.tr

Citation Information
Sarı, M. H. & Bostancıoğlu, A. (2018). Application of Technological Pedagogical Content Knowledge framework to elementary mathematics teaching: A scale adaptation study. *Kuramsal Eğitimbilim Dergisi [Journal of Theoretical Educational Science], 11*(2), 296-317.

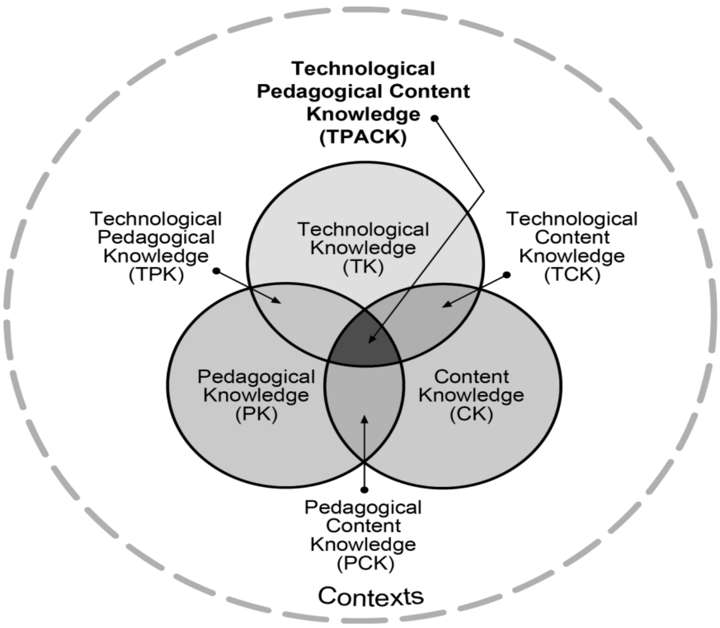
ISSN: 1308-1659

Introduction

Considering that any investment made in education is a direct investment in humanity, it is inevitable that there will be extensive investments in education and educational technology in particular. In line with this, investments in technology have increased around the world in an effort to increase the quality of education (Macaro, Handley, & Walter, 2012). Undoubtedly, this trend has also affected our country (Turkey) and, with FATIH (the movement of increasing opportunities and improving technology; FATİH, n.d.) being the most recent one, there has been a number of different investments around the country in order to increase the use of technology in education. In addition to that, active use of technology is now stipulated in the curriculum of subjects (i.e. science and mathematics; Turkish Board of Education [TTKB], n.d.; Sarı & Akbaba-Altun, 2015). The use of technology in mathematics teaching can help students gain a better understanding of mathematics by providing opportunities to develop different perspectives and techniques to solve problems, and evaluating the significance and validity of (Erbaş, 2005). When the mathematics curriculum is analysed, it can be seen that the need to raise students who can use information in the process of solving problems, apply it to different disciplines, think analytically, make generalizations, and approach the problems they encounter with a mathematical reasoning has been emphasized (MEB, 2009a; MEB, 2009b; MEB, 2011). It is acknowledged that technology can potentially have a big impact in reaching these goals. In addition to this, the integration of technology into the teaching/learning process has brought a number of changes in roles adopted by stakeholders (i.e. teachers and students). In fact, teachers are the stakeholders who have been most affected by this change (Ely, 1992; Tezci & Perkmen, 2013). It is reported that the more successful experiences teachers have with the use of technologies in the teaching/learning process, the closer they are to using technology in their classrooms, then the more appropriate and effective their use of technology in the classrooms becomes (Powers & Blubaugh, 2005).

Educational technologists, however, state that equipping classrooms with technology does not necessarily mean they are used effectively. For example, Mishra and Koehler (2006) underline that technology can be used effectively only when the possibilities it offers is integrated with the content to be taught and associated theories of learning. This suggests that teachers' ability to use technology effectively and appropriately is related to their "technological pedagogical and content knowledge" (TPACK; Mishra & Koehler, 2006). Building on Shulman's (1987) concept of pedagogical content knowledge (PCK) which integrates pedagogy knowledge (PK) and content knowledge (CK), Mishra and Koehler (2006) added technology knowledge (TK) as a new dimension and created the TPACK framework. When each of these core knowledge bases (TK, PK, and CK) is considered as circles, the area where all of them intersect can be considered as TPACK (see Figure 1; Mishra & Koehler, 2006).

Figure 1. The TPACK Framework



Source: http://tpack.org/. Reproduced by permission of the publisher, © 2012 by tpack.org.

TPACK is a framework developed to better understand the process in which teachers integrate technology into their teaching. In this framework, a teacher's effectiveness is argued to be related to their ability to harmonize their TK, PK, and CK (Mishra & Koehler, 2006). TK underlines teachers' understanding of how to operate technologies that can be used for educational purposes; PK highlights teachers' understanding of the conditions necessary for and processes involved in learning and common approaches to and methods of teaching; and CK stand for teachers' level of understanding of the subject matter to be taught and how the subcomponents of the subject matter are interrelated (Mishra & Koehler, 2006). The interaction between these three knowledge bases creates four new dimensions; Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPCK[1]; Mishra & Koehler, 2006). PCK refers to teachers' knowledge and awareness of various ways in which they can transform the subject matter into representations that promote learning and understanding among students (Shulman, 1986). TCK, similar to PCK, refers to the knowledge that teachers need to be able to use technology to transform the subject matter into representations that promote learning. TPK refers to the knowledge that teachers need to be able to use technology to actively engage learners in the learning process and create suitable conditions that foster learning in general. Finally, TPACK refers to the knowledge that teacher need to be able to integrate technology and content in pedagogically sound ways (Mishra & Koehler, 2006).

Due to simplified explanations the framework provides and its flexibility, TPACK has become a popular framework used in the process of planning and/or analysing technology integration into the teaching and learning environment (see Chai,

[1] TPACK abbreviation is used to refer to Mishra and Koehler's framework as a whole while TPCK is used to refer to the central component of the framework.

Koh, & Tsai; Koehler, Shin, & Mishra, 2012; Voogt, Fisser, Roblin, Tondeur, & van Braak, 2012). Likewise, the framework has been mentioned in research studies in different ways. While a number of scientists developed course designs in accordance with the TPACK framework (Akkoç & Yeşildere-İmre, 2015; Özgelen, 2013), few utilized the theory to measure the effect of technology related in-service training on teachers' professional development (Angeli & Valanides, 2009), and some utilized the framework to understand the process in which teachers make decisions to use technology (Graham, Borup, & Smith, 2012). Most research studies, however, focused on developing/adapting tools that can be used in measuring teachers' TPACK levels (Archambault & Barnett, 2010; Canbazoğlu-Bilici, Yamak, Kavak, & Guzey, 2013; Cox & Graham, 2009; Doering, Koseoglu, Scharber, Henrickson, & Lanegran, 2014; Koh, Chai, & Tsai, 2010; Schmidt et al., 2009).

In line with the aim of the present study, relevant literature on subject-specific (i.e. science, social sciences, mathematics) as well as generic TPACK scale development studies are reviewed below.

Generic TPACK Scale Development/ Adaptation Studies

One of the first examples of scale development studies for the TPACK framework is Schmidt et al.'s (2009) generic TPACK scale designed for pre-service teachers. This scale has established its presence in the literature as the most adapted TPACK scale both in our country (Turkey) and the world. Following Schmidt et al.'s (2009) study, Archambault and Barnett (2010) developed a 24-item generic TPACK scale and administered it to 596 teachers teaching online classes in the United States. The Exploratory Factor Analysis (EFA) results in this study revealed three factors of the TPACK framework: TK, PCK, and TPCK. On the other hand, in their study that has been conducted with 1185 pre-service teachers studying in universities across Singapore, Koh et al.'s (2010) EFA results yielded a TPACK questionnaire with five dimensions: TK, CK, PCK, TPCK, and Knowledge from Critical Reflection (KCR). In another TPACK study, Chai et al. (2011) administered their survey to 834 pre-service teachers studying at universities in Singapore. Their EFA results suggested a five-factor solution: TK, CK, PCK, TPK, and TPCK (see Table 1 below). In their study focusing on adaptation of Schmidt et al.'s (2009) TPACK scale into Turkish, Öztürk and Horzum (2011) administered their survey to 291 in-service teachers. Their EFA results revealed all dimensions of the TPACK framework and these results were supported with a confirmatory factor analysis (CFA). On the other hand, in their study conducted with 365 pre-services teachers who were registered in an educational technology course in the United States, Shinas et al. (2013) found a four-factor solution after their EFA: CK, PK, TK, and TPK. In another study conducted with participation of 2728 K-12 teachers, Liu et al. (2015) adapted the TPACK framework developed by Koh et al. (2014) into Chinese and their EFA results yielded a five-factor solution: PK, CK, TK, PCK, and TPCK. In another study conducted in Turkey, Pamuk et al. (2015) administered their generic TPACK survey to 147 teacher candidates and they were able to establish the seven dimensions of the TPACK framework after EFA. Finally, Sang et al. (2016) administered the TPACK scale they developed to 229 pre-service teachers studying at Chinese universities. They were able to both establish the seven dimensions of the

TPACK framework after EFA and also found an eight-factor solution that they named Technology Knowledge about World Wide Web (see Table 1) [1].

Table 1

Factors Found in Generic TPACK Studies

Study	Country	Participants	Sample size	Factors found
Archamabult & Barnett (2010)	United States	Online K-12 teachers	596	3: TK, PCK (= PCK + PK + CK), TPACK (= TPACK + TPK + TCK)
Koh et al. (2010)	Singapore	Pre-service teachers	1185	5: TK, CK, PCK (= PCK + PK), TPACK (= TPACK + TPK + TCK), Knowledge from Critical Reflection (KCR)
Chai et al. (2011)	Singapore	Pre-service teachers	834	5: PK, TK, CK, TPK, TPACK
Öztürk & Horzum (2011)	Turkey	Primary school teachers	291	7: TK, PK, CK, PCK, TCK, TPK, TPACK
Shinas et al. (2013)	United States	Pre-service teachers	365	4: CK, PK (= PK + PCK), TK, TPK (= TPK + TPACK)
Liu et al. (2015)	China	K-12 teachers	2728	5: TK, PK, CK, PCK, TPACK (= TPACK + TPK + TCK)
Pamuk et al. (2015)	Turkey	Pre-service teachers	147	7: TK, PK, CK, PCK, TCK, TPK, TPACK
Sang et al. (2016)	China	Pre-service teachers	229	8: TK, PK, CK, PCK, TCK, TPK, TPACK, Technology Knowledge about World Wide Web (TKW)

When above TPACK scale development/adaptation studies are examined, it can be concluded that those generic surveys do not necessarily allow the use of the TPACK framework in a way that would suit every subject and context. The reason for this may be the fact that it is not possible to sufficiently articulate the CK in generic TPACK surveys. For example, Koh et al. (2010, p. 568) used the following statement to refer to CK: "I have sufficient knowledge about my Curriculum Subject 1". It can be considered that this will not only affect the CK but also PCK, TCK, and TPACK. As such, the need to develop subject-specific TPACK instruments has been highlighted by researchers (Chai et al., 2013; Koehler et al., 2012; Voogt et al., 2012).

[2] Since there is a great number of TPACK related scale development studies, this review of literature is limited to those studies that used factor analytic techniques in analyzing data.

Subject Specific TPACK Scale Development/ Adaptation Studies

The suggestions to develop subject specific TPACK assessment tools have been taken into consideration by researchers and as a result of this; for example, studies focusing on developing TPACK scales for mathematics, science, and English as a foreign language (EFL) have been conducted (see Table 2). Canbazoğlu-Bilici et al. (2013) developed a TPACK scale for science teaching. It can be observed that, unlike generic TPACK scales, the CK dimension in this scale is more clearly articulated in questionnaire items (i.e. "I can explain various chemistry concepts", p. 57). They administered their scale to 808 pre-service science teachers studying across universities in Turkey. Their EFA results yielded all of the seven factors of the TPACK framework and, in addition, Context Knowledge (CK) emerged as the eighth factor.

In another study conducted in Turkey and focusing on mathematics teaching, Dikkartın-Övez and Akyüz (2013) developed a scale for mathematics teaching and administered it to 473 pre-school secondary mathematics teachers. Their EFA results suggested a four-factor solution: CK, TK, PCK, and TPCK. In another study conducted in the field of TPACK and mathematics teaching, Zelkowski et al. (2013) also identified four factors of the TPACK framework: TK, CK, PK, and TPCK. In a different study conducted in Turkey, Başer et al. (2016) have applied the TPACK framework to EFL teaching. They administered the survey to 204 pre-service EFL teachers and the EFA results yielded a seven-factor solution where all dimensions of the framework emerged as individual factors. Finally, Su et al. (2017) have administered their TPACK scale developed for geography teaching to 869 in-service geography teachers teaching in Chinese schools and their CFA results also confirmed the seven-factor structure of the TPACK framework.

Table 2

Factors Found in Subject Specific TPACK Studies

Study	Country	Participants	Sample Size	Factors found
Canbazoğlu-Bilici et al. (2013)	Turkey	Pre-service science teachers	808	8: TK, PK, CK, PCK, TCK, TPK, TPACK, Context Knowledge (CxK)
Dikkartın-Övez & Akyüz (2013)	Turkey	Pre-service mathematics teachers	473	4: TK, CK, PCK, TPACK
Zelkowski et al. (2013)	United States	Pre-service mathematics teachers	294	4: TK, CK, PK, TPACK
Başer et al. (2016)	Turkey	Pre-service EFL teachers	204	7: TK, PK, CK, PCK, TCK, TPK, TPACK
Su et al. (2017)	China	Geography teachers	869	7: TK, PK, CK, PCK, TCK, TPK, TPACK

As seen from subject specific and generic TPACK scale development/adaptation studies, TPACK has been studied in different countries (i.e. China, United States, and Turkey) and with both in-service and pre-service teachers as well as teachers teaching in online contexts. However, the review of literature suggested that there were not any TPACK scales available for elementary mathematics teaching (year 1-4) in the Turkish context. Even though there were a number of TPACK scales specifically developed for mathematics teaching (Dikkartın-Övez & Akyüz, 2013; Zelkowski et al., 2013), the participants in those studies were pre-service teachers and the scales were developed for secondary school mathematics teaching.

In the present study, the reason for why we focus on applying TPACK to elementary mathematics teaching and recruit in-service teachers as our participants can be summarized as following: 1) elementary school (year 1-4) is a period in which there should be abundant practices that utilize technology in mathematics teaching and 2) the necessity to include technological tools and applications in the teaching/learning process since students studying at this level are at concrete operational stage of cognitive development (Sarı & Özerbaş, 2013). Therefore, it can be argued that teachers who work at this level and teach mathematics need to have a satisfactory level of technological pedagogical and content knowledge. Taking above discussions into consideration, the present study aims to adapt Zelkowski et al.'s (2013) TPACK scale for mathematics teaching into Turkish in an effort to develop a valid and reliable TPACK that can be used in teachers' assessment of their levels of TPACK for elementary mathematics teaching.

Method

Participants

The participants in this study were classroom teachers working in public schools in Nevşehir, Gaziantep, and Hatay provinces of Turkey. A maximum likelihood purposeful sampling strategy was followed (Büyüköztürk, Kılıç, Akgün, Karadeniz & Demirel, 2008). With regards to this, teachers working in schools within city centres as well as villages and counties were approached. During the administration of the scale, three items were reversed to identify mechanic responses. 123 responses which have been identified to be mechanic and/or missing answers to more than five items have been excluded from the analysis. This resulted in a total of 372 responses for Exploratory Factor Analysis (EFA) and 310 responses were used for Confirmatory Factor Analysis (CFA). In addition, the items reversed to prevent mechanic responses were not included in the analysis stage.

Data Collection Tool

The scale developed by Zelkowski, Gleason, Cox, and Bismarck (2013) and titled "TPACK Instrument for Secondary Mathematics Pre-service Teachers" has been used in this study. The language of this scale is English. In the original scale, each item was assessed on a five-point Likert scale: 1) *"strongly disagree"*, 2) *"disagree"*, 3) *"neither agree nor disagree"*, 4) *"agree"*, and 5) *"strongly agree"*. In their attempt to validate their 62-item TPACK questionnaire, Zelkowski et al.'s EFA and CFA resulted in a 23-item scale under four factors. The present study aimed to first translate

Zelkowski et al.'s (2013) whole survey (62-items) into Turkish and then administer it to teachers and analyse the data using factor analytic approaches (EFA and CFA). In addition, the scale items were adapted to suit elementary mathematics teaching. During this adaptation process, attention was paid to using mathematical concepts that are included in elementary mathematics curriculum (MEB, 2015). For example, concepts such as "trigonometry" and "derivatives" which are included in Zelkowski et al.'s (2013) scale have been replaced by "geometry" and "calculus" respectively since the former ones was not included in elementary mathematics curriculum.

The process in which the scale was translated into Turkish can be summarized as the following. Firstly, the scale was translated into Turkish by a lecturer who completed his MA and PhD studies in the UK and who, at the time of research, worked in the English language teaching department. After this, the translated (Turkish) items were retranslated into English and the consistency between the original scale and its Turkish equivalence was evaluated. As such, both the Turkish and English versions of the scale were sent to two professors working in the "Computer and Educational Technologies" departments to test the language validity. Furthermore, the Turkish version of the survey was checked by a lecturer working in Turkish language teaching department and the survey was piloted with 10 pre-service classroom teachers prior to administration. Based on feedback received from education technologist professors, a number of items were reworded and the Turkish version of the scale was finalised. This final version was titled as "The Adaptation of the Technological Pedagogical and Content Knowledge (TPACK) Framework into Elementary Mathematics (EM) Teaching".

Data Analysis

Both Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) methods were used in order to establish the construct validity of the scale adapted to Turkish. EFA can be carried out to establish validity and reveal the latent dimensions of a questionnaire translated from one culture (Erkuş, 2003). Therefore, EFA, in this study, was used to determine under what factors do the items in the Turkish version of the scale load and understand the structure of the scale in the Turkish context. As for reliability, Cronbach's alpha *(α)* internal consistency levels was calculated. CFA, on the other hand, can be used to confirm the structure of a previously defined and/or limited construct (Çokluk, Şekercioğlu, & Büyüköztürk, 2012). In other words, it is a technique that is used to test structures established with EFA (Çokluk et al., 2012). Therefore, the structure of the scale developed after EFA was tested with CFA.

Findings

Construct Validity

Exploratory Factor Analysis (EFA): Prior to "Exploratory Factor Analysis", the data set was analyzed to confirm its fit for factor analysis using Keiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity (see Table 3).

Table 3

KMO and Bartlett's Test of Sphericity Results

Kaiser-Meyer-Olkin (KMO) Value		.960
Bartlett's Test Value	Chi-Square	13067.76
	df	1081
	Sig.	.000

As can be seen in Table 3, Bartlett's test of sphericity is significant *(p<.01)* and KMO value is .960 (0.800 and above are acceptable levels according to Alpar, 2014). Therefore, it is concluded that the dataset is fit for factor analysis (Alpar, 2014; Büyüköztürk et al., 2009). After this, EFA was conducted and results are presented in Table 4.

Table 4

Results of Exploratory Factor Analysis for Technological Pedagogical and Content Knowledge Scale for Mathematics Teaching

Factors	Eigen Values	Variance Explained (%)	Cumulative Variance (%)
1	27.835	44.895	44.895
2	3.282	5.293	50.188
3	2.858	4.610	54.798
4	1.950	3.146	57.944
5	1.877	3.027	60.971
6	1.458	2.351	63.322
7	1.387	2.237	65.559
8	1.259	2.031	67.589
9	1.116	1.801	69.390
10	1.051	1.696	71.086

The principle component analysis technique was used for EFA. The results showed that there are 10 factors with an Eigen value higher than 1.00 (see Table 4). Although this suggests a 10-factor solution, when the Scree Plot is analysed, it can be observed that there inflection occurs on the third factor (see Figure 2). Relevant literature on this matter suggests that the factor structure can be evaluated as +1 or -1 factors from the inflection point (Field, 2009). The analysis in this study suggested that a four-factor solution was fit for "Technological Pedagogical and Content Knowledge" scale compared to other solutions.

After deciding on the number of factors, principle components analysis was re-run to extract four factors. In this process, attention was paid to items that had loaded onto more than one factor. It is suggested that the difference between an item's loadings onto more than one factor be higher than .10 (Büyüköztürk, 2010). Therefore, 15 items which have been identified to load onto more than one factor and with differences between factor loadings being lower than 0.1 were deleted and EFA was re-run using Varimax rotation (see Table 5).

Figure 2. Scree Plot of Factor Loadings

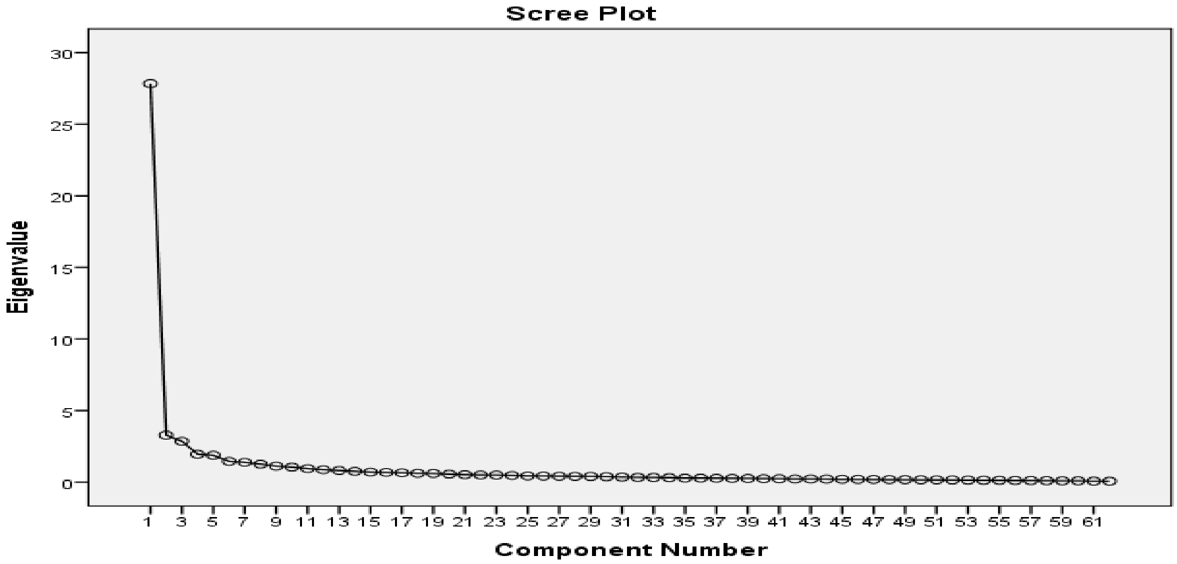


Table 5

Factor Loadings and Variance Results of Rotated Principle Component Analysis for Technological Pedagogical and Content Knowledge Scale for Mathematics Teaching

Factors					Variance Explained (%)
Items	KTMT	KTM	CKM	TK	
ITEM5	.763				
ITEM11	.750				
ITEM7	.720				
ITEM8	.695				
ITEM10	.693				
ITEM12	.684				
ITEM6	.679				
ITEM3	.648				
ITEM26	.599				
ITEM27	.595				
ITEM2	.585				20.66
ITEM1	.576				
ITEM13	.570				
ITEM22	.564				
ITEM23	.560				
ITEM28	.553				
ITEM14	.547				
ITEM21	.545				
ITEM20	.524				
ITEM4	.511				
ITEM40		.796			19.41
ITEM37		.795			

ITEM39		.790			
ITEM38		.767			
ITEM43		.734			
ITEM35		.688			
ITEM42		.660			
ITEM30		.659			
ITEM36		.659			
ITEM34		.616			
ITEM41		.586			
ITEM31		.547			
ITEM33		.530			
ITEM48			.763		
ITEM49			.745		
ITEM45			.679		
ITEM44			.672		11.74
ITEM46			.661		
ITEM50			.638		
ITEM51			.617		
ITEM47			.589		
ITEM56				.783	
ITEM57				.756	
ITEM53				.737	10.37
ITEM54				.735	
ITEM55				.702	
ITEM58				.655	
Total	47 items				% 62.20

KTMT: *Knowledge of Teaching Mathematics with Technology,* ***KTM:*** *Knowledge of teaching Mathematics,* ***CKM:*** *Content Knowledge for Mathematics,* ***TK:*** *Technology Knowledge*

When the items loaded onto different factors are analysed, it can be observed that Technological Pedagogical Content Knowledge (TPCK), Technological Pedagogical Knowledge (TPK), and Technological Content Knowledge (TCK) items loaded onto the first factor. There are 20 items in this factor (i.e. "ITEM 10- I can teach lessons that appropriately combine geometry, technologies, and teaching approaches" and "ITEM 28- I know that using appropriate technology can improve one's understanding of mathematics concepts"). ITEM 4 has the lowest loading (.511) within this factor and ITEM 5 has the highest (.763). In line with Koh et al.'s findings (2010) - who also found that TPK, TCK, and TPCK factors merged together- this factor has been named as Knowledge of Teaching Mathematics with Technology (KTMT).

The second factor in the scale (see Table 3) consists of Pedagogy Knowledge (PK) and Pedagogical Content Knowledge (PCK) items. There are 13 items in this factor (i.e. "ITEM 35- I know different strategies/approaches for teaching calculus concepts" and "ITEM 38- I can adapt my teaching style to different learners"). ITEM 33 has the lowest loading (.530) within this factor and ITEM40 (.796) has the highest. This second factor has been named as Knowledge of Teaching Mathematics (KTM).

The third factor in the scale consists of Content Knowledge (CK) items. There are eight items in this factor (i.e. "ITEM 49- I have a deep and wide understanding of geometry" and "ITEM 45- I can use mathematical ways of thinking"). ITEM 47 has the lowest loading (.589) and ITEM 48 the highest (.763). This factor has been named Content Knowledge for Mathematics (CKM). When the last factor is analysed, it can be observed that the items in this dimension are Technology Knowledge (TK) items. There are a total of six items in this factor (i.e. "ITEM 53- I can learn technology easily" and "ITEM 54- I keep up with important new technologies") and ITEM 58 has the lowest loading (.655) while ITEM 56 the highest (.783).

When the results of this 47-item scale are analysed, it can be observed the lowest factor loading is .511 (ITEM4) and the highest is ITEM40 (.796). In addition, the first factor explains 20.66 % of the variance, second 19.41 %, third 11.74 %, and the last and fourth 10.37%. This four-factor solution explains 62.20 of the total variance in the scale (see Table 5).

Confirmatory Factor Analysis (CFA): In order to test the four-factor solution reached after EFA, 310 responses from classroom teachers were used for CFA in two stages. In the first stage the model fit was analysed without applying limitations. The model fit indices obtained in this analysis were; x^2/sd 4717.91/1028= 4.59, RMSEA .09, RMR .06, NNFI .97, NFI .96, CFI .97, and IFI .97.

During the analysis of the modification indices obtained in CFA, it is suggested that items be covaried if the change suggested by covarying these values contributes to x^2 value (Şimşek, 2007; Çokluk et al., 2012). Therefore, the modification indices obtained in the CFA were scanned for covariance of items suggested by in the analysis. This was the case for ITEM 12-13, ITEM 14-15, ITEM 16-17, ITEM 17-18, ITEM 18-19, ITEM 29-30, ITEM 32-33, ITEM 48-49, and ITEM 52-53. After co-varying the above items, the RMSEA value became .07, RMR .06, NNFI .98, NFI .97, CFI .98, and IFI .98. The x^2/sd value became 3265.91/1019= 3.20. The model fit indices suggested in the literature are given in Table 6 (Karagöz, 2016).

Table 6

Model Fit Values for Structural Equation Model

Model Value Criteria	Good Fit	Acceptable Fit
x^2/sd	≤ 3	≤ 5
NNFI	$0.95 \leq$ NNFI	$0.90 \leq$ NNFI
NFI	$0.95 \leq$ NFI	$0.90 \leq$ NFI
IFI	$0.95 \leq$ IFI	$0.90 \leq$ IFI
CFI	$0.97 \leq$ CFI	$0.95 \leq$ CFI
RMSEA	RMSEA ≤ 0.05	RMSEA ≤ 0.08
RMR	$0 <$ RMR ≤ 0.05	$0 <$ RMR ≤ 0.08

It can be seen in Table 6 that while NNFI, NFI, CFI, and IFI values show a good fit for the model obtained in our analysis, x^2/sd, RMSEA, and RMR values show an acceptable fit. The Path diagram of the results is available in Figure 3.

One of the methods to provide evidence of construct validity is providing details of factor correlations (Şencan, 2005). Therefore, factor correlations were calculated using total scale scores of participants and the results of this analysis are presented in Table 7.

Table 7
Results of Factor Correlation Analysis Based on Total Scale Scores

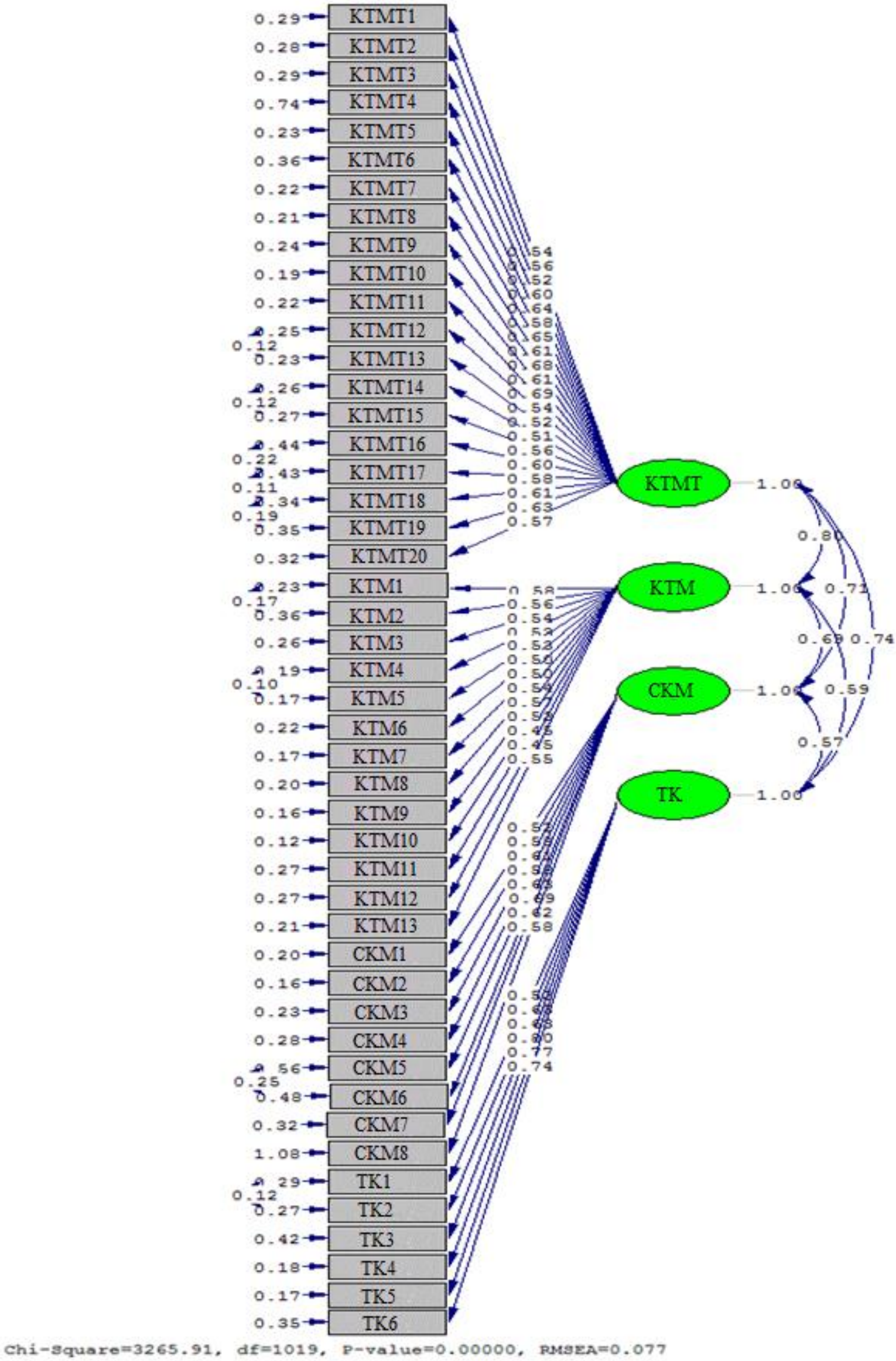
		KTMT	KTM	CKM	TK
Total scores	Pearson Correlation (r)	.950	.866	.782	.766
	Sig. (p)	000*	000*	000*	000*
Knowledge of Teaching Mathematics with Technology (KTMT)	Pearson Correlation (r)	-	.750	.646	.688
	Sig. (p)	-	000*	000*	000*
Knowledge of Teaching Mathematics (KTM)	Pearson Correlation (r)	-	-	.604	.543
	Sig. (p)	-	-	000*	000*
Content Knowledge for Mathematics (CKM)	Pearson Correlation (r)	-	-	-	.512
	Sig. (p)	-	-	-	000*
Technology Knowledge (TK)	Pearson Correlation (r)	-	-	-	-
	Sig. (p)	-	-	-	-

* *Correlations are meaningful at the level of (**p<.001)*

The analysis of the relationship between scale total scores and each of the sub-dimensions showed that a strong relationship exist between the scale total scores and each sub-dimension (*r*= .950 for KTMT, .866 for KTM, .782 for CKM, and .766 for TK; *p*<.01). The analysis of the relationship among the sub-dimensions also showed that there was a moderate to strong relationship among all factors (i.e. .750 between KTMT and KTM, and .512 between CKM and TK; *p*<.01).

Şencan (2005) states that if the factor solution reached includes two to four factors and if the correlations among the factors are high (above .60) then it can be concluded that the factors depend on each other and measure one construct. Based on this, it can be inferred that each of the factors that emerged in this study measures a sub-dimension of one construct which is the TPACK of teachers.

Figure 3. Path Diagram of the Results



Reliability of the Scale

In order to establish the reliability of the scale Cronbach's Alpha *(α)* internal consistency values and item total correlations were calculated and presented in Table 8.

Table 8

Item Total Correlation (r), Means (X), Standard Deviation (Sx), and Cronbach's Alpha (α) Values

Items			
Knowledge of Teaching Mathematics with Technology *Cronbach's Alpha (α) value =.96*	r	x	Sx
I can teach lessons that appropriately combine mathematics, technologies, and teaching approaches.	.736	4.081	.808
I can teach lessons that appropriately combine measurement concepts, technologies, and teaching approaches.	.740	4.065	.748
I can teach lessons that appropriately combine fraction concepts, technologies, and teaching approaches.	.748	4.044	.803
I can teach lessons that appropriately combine probability and statistics, technologies, and teaching approaches.	.744	4.007	.778
I can teach lessons that appropriately combine geometry, technologies, and teaching approaches.	.754	4.035	.853
I can teach lessons that appropriately combine calculus, technologies, and teaching approaches.	.786	4.115	.823
Integrating technology in teaching mathematics will be easy and straightforward for me.	.605	3.892	.843
I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.	.640	4.313	.734
I know about technologies that I can use for understanding and doing measurement.	.722	3.871	.887
I know about technologies that I can use for understanding and doing calculus.	.738	4.014	.882
I can choose technologies that enhance the mathematics for a lesson.	.716	4.248	.759
I can use strategies that combine mathematics, technologies, and teaching approaches that I learned about in my coursework in my classroom.	.676	4.164	.769
I can choose technologies that enhance the teaching of a lesson.	.772	4.171	.733
I know about technologies that I can use for understanding and doing fractions.	.700	3.968	.907
I know about technologies that I can use for understanding and doing probability and statistics.	.668	3.819	.886
I know that using appropriate technology can improve one's understanding of mathematics concepts.	.697	4.199	.807
I can choose technologies that enhance students' learning for a lesson.	.742	4.242	.702
I know how to use technology in different instructional approaches.	.725	4.124	.753
I have the classroom management skills I need to use technology appropriately in teaching.	.707	4.163	.708
I can provide leadership in helping others to coordinate the use of mathematics, technologies, and teaching approaches at my school and/or district.	.557	3.326	1.05
Knowledge of Teaching Mathematics *Cronbach's Alpha (α) value =.94*			
I can use a wide range of teaching approaches in a classroom setting.	.650	4.435	.622
I can adapt my teaching based upon what students currently understand or do not understand.	.599	4.463	.640
I can assess student learning in multiple ways.	.666	4.372	.679

Table 8

Item Total Correlation (r), Means (X), Standard Deviation (Sx), and Cronbach's Alpha (α) Values

Items			
I can adapt my teaching style to different learners.	.590	4.286	.706
I know when it is appropriate to use a variety of teaching approaches (e.g., problem/project-based learning, inquiry learning, collaborative learning, and direct instruction) in a classroom setting.	.664	4.327	.722
I know different strategies/approaches for teaching calculus concepts.	.726	4.327	.667
I know how to organize and maintain classroom management.	.560	4.391	.700
I know different strategies/approaches for teaching fraction concepts.	.747	4.222	.728
I know how to assess student performance in a classroom.	.670	4.463	.649
I know different strategies/approaches for teaching measurement concepts (e.g. length, surface area, and liquid).	.752	4.314	.701
I am familiar with common student understandings and misconceptions.	.575	4.248	.690
I know different strategies/approaches for teaching probability and statistics concepts.	.673	4.013	.822
I know different strategies/approaches for teaching geometry concepts.	.720	4.152	.757
Content Knowledge for Mathematics			
Cronbach's Alpha (α) value =.89			
I have a deep and wide understanding of algebra.	.497	3.632	.970
I have a deep and wide understanding of geometry.	.602	3.761	.969
I can use mathematical ways of thinking.	.621	4.283	.689
I have sufficient knowledge about mathematics.	.545	4.364	.672
I have various strategies for developing my understanding of mathematics.	.613	4.086	.770
I have a deep and wide understanding of calculus.	.629	4.095	.845
I have a deep and wide understanding of advanced undergraduate mathematics.	.393	2.873	1.24
I know about various examples of how mathematics applies in the real world.	.639	4.193	.791
Technology Knowledge			
Cronbach's Alpha (α) value =.91			
I know about a lot of different technologies.	.667	3.714	.897
I have the technical skills I need to use technology.	.675	3.875	.879
I can learn technology easily.	.592	4.267	.757
I keep up with important new technologies.	.656	4.113	.823
I frequently play around with the technology.	.486	3.745	.899
I have had sufficient opportunities to work with different technologies.	.639	3.652	.964
Total			
Cronbach's Alpha (α) value =.97			

It can be seen in Table 8 that the Cronbach's Alpha internal consistency value for the whole scale is .97. When each dimension within the scale is analysed, it can be seen that the internal consistency for knowledge of teaching mathematics with technology is .96, .94 for knowledge of teaching mathematics, .89 for content knowledge for mathematics, and .91 for technology knowledge. In addition, it can be seen that total item correlations for all items are above .30 and, in fact, high.

Discussion, Conclusion and Implications

The present study's aim was to adapt technological pedagogical and content knowledge scale into Turkish. In line with this aim, the adaptation of the scale took place in three stages. In the first stage, the language validity of the scale was established through translation of the survey from English to Turkish and then from Turkish to English by language experts. In the second stage, the construct validity of the survey was established and the reliability was established in the third stage. The construct validity of the survey was established by applying Exploratory Factor Analysis (EFA) and confirmatory factor analysis (CFA) and the reliability was established by calculating the Cronbach's Alpha internal consistency *(α)* and item total correlations.

The EFA analysis conducted to establish the construct validity of the scale suggested a four-factor solution. Items from Technological Pedagogical Content Knowledge (TPCK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK) dimensions were gathered under the first factor and this factor was named Knowledge of Teaching Mathematics with Technology (KTMT). Similarly, items from Pedagogical Content Knowledge (PCK) and Content Knowledge (CK) dimensions were gathered under the second factor and this factor was named Knowledge of Teaching Mathematics (KTM). As for the items gathered under the third factor, they belonged to the Content Knowledge (CK) dimension which was named Content Knowledge for Mathematics (CKM). Similarly, the items gathered under the fourth and last factor belonged to the Technology Knowledge (TK) dimension. Thus, the last factor was named TK.

The four-factor solution found in the present study is similar to Zelkowski et al.'s (2013) factor analysis results except in the latter PCK, TCK, and TPK items were all deleted from the analysis since items in each sub-scale loaded onto various factors with no obvious pattern. One interpretation of these findings is that in Zelkowski et al.'s (2013) study, teachers were not able to differentiate between the different dimensions of the TPACK framework even those that were closely associated (i.e. PK and PCK, or TPK and TCK). Though a similar four factor solution was achieved in the present study, the fact that no TPACK factors were deleted (but rather merged together) suggests that teachers were able to recognize the difference between the main components of the TPACK framework (TK, CK, and PK) but were not able to differentiate between the more sophisticated second level factors (i.e. TPK, TCK, and TPCK). In fact, Dikkartın-Övez and Akyüz's (2013) results were the same in terms of the number of factors found and the way in which factors merged together (i.e. the merge of PK and PCK).

There are a number of possible explanations for the above results. First of all, researchers generally explain that such results arise due to the TPACK framework not being comprehensive enough and the fact that construct boundaries within TPACK dimensions are not clear (Angeli & Valanides, 2009; Cox, 2008; Graham, 2011). In fact, the fact that Pedagogy Knowledge (PK) and Pedagogical Content Knowledge (PCK) merged together as one factor was an expected outcome. It is generally stated in the literature that PK and Content Knowledge (CK) are intrinsically linked because of their nature. As Segall (2004) explains, if we accept that pedagogy is not restricted to the classroom and refers broadly to process of transmitting and reproducing knowledge (Simon, 1992), and that any expression of subject matter is an attempt to communicate understanding thereof (McEwan & Bull, 1991), then “pedagogy would be inherent in any message” (Segall, 2004, p. 494).

The reason for why Technology Knowledge (TK) emerged as a separate factor on its own can be explained as; the technology related education that teacher candidates receive throughout their pre-service teacher education is generally focused on the technical aspects of technology and such courses do not focus how technology, pedagogy, and technology interrelate (consider for example the Information and Communication Technologies courses offered to teacher candidates in Education Faculties across the country; see also Chai et al., 2011; Lawless & Pellegrino, 2007). The fact that TPACK, TPK, and TCK merged together as one factor can be explained as; when experienced teachers plan the teaching of a subject, it is considered the way they plan it (PK) is also “part and the parcel of the content” (CK). It is considered that technology (TK), when added to this equation, becomes a natural part of this parcel and this makes it difficult to distinguish between different aspects of the content (CK), pedagogy (PK), and technology (TK; Archambault & Barnett, 2010, p. 1659).

While the aim of the present study was to confirm the seven-factor structure of the TPACK framework, the results suggested a four-factor solution. Apart from the reasons explained above, one of the reasons for this outcome might have been the teachers who participated in this study. Therefore, a study that will further investigate this issue with a bigger sample of teachers is encouraged. Nevertheless, taking all the results obtained in this study into consideration, it can be concluded that the Technological Pedagogical and Content Knowledge scale developed for classroom teachers and elementary mathematics teaching can be used in measuring teachers’ TPACK levels. With regards to this, classroom teachers’ levels of TPACK in relation to elementary mathematics teaching can be investigated using the final version of the scale. Last but not least, the scale can be used as a diagnostic tool to be used to assess needs of teachers who would receive training on the use of technology in mathematics teaching.

References

Akkoç, H., & Yeşildere-İmre, S. (2015). *Teknolojik pedagojik alan bilgisi temelli olasılık ve istatistik öğretimi* (1. ed.): Ankara: Pegem Akademi.

Alpar, R. (2014). *Spor, sağlık ve eğitim bilimlerinde uygulamalı istatistik ve geçerlik-güvenirlik*. (Üçüncü Baskı). Ankara: Detay Yayıncılık.

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for conceptualization, development, and assessment of ICT-PCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & Education, 52*(1), 154-168.

Archambault, L. M., & Barnett, J. H. (2010). Revisiting technological pedagogical content knowledge: Exploring the TPACK framework. *Computers & Education, 55*, 1656-1662.

Baser, D., Kopcha, T. J., & Ozden, M. Y. (2016). Developing a technological pedagogical content knowledge (TPACK) assessment for preservice teachers learning to teach English as a foreign language. *Computer Assisted Language Learning, 29*(4), 749-764.

Büyüköztürk, Ş. (2010). *Sosyal bilimler için veri analiz el kitabı.* Ankara: Pegem A. Yayıncılık.

Büyüköztürk, Ş., Çakmak, E.K., Akgün, Ö.E., Karadeniz, Ş., & Demirel, F. (2008). *Bilimsel araştırma yöntemleri.* (4.Baskı) Ankara: Pegem A Yayıncılık.

Canbazoğlu-Bilici, S., Yamak, H., Kavak, N., & Guzey, S. S. (2013). Technological pedagogical content knowledge self-efficacy scale (TPACK-SeS) for pre-service science teachers: Construction, validation, and reliability. *Eurasian Journal of Educational Research, 52*, 37-60.

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

Chai, C.-S., Koh, J. H.-L., Tsai, C.-C., & Tan, L. L. W. (2011). Modeling primary school pre-service teachers' technological pedagogical content knowledge (TPACK) for meaningful learning with information and communication technology (ICT). *Computers & Education, 57*, 1184-1193.

Çokluk, Ö., Şekercioğlu, G., & Büyüköztürk, Ş. (2012). S*osyal bilimler için çok değişkenli istatistik SPSS ve LISREL uygulamaları. (İkinci Baskı).* Ankara: Pegem A. Yayıncılık.

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

Dikkartın-Övez, F. T., & Akyüz, G. (2013). Modelling technological pedagogical content knowledge constructs of preservice elementary mathematics teachers. *Education and Science, 38*, 321-334.

Doering, A., Koseoglu, S., Scharber, C., Henrickson, J., & Lanegran, D. (2014). Technology integration in K–12 geography education using TPACK as a conceptual model. *Journal of Geography, 113*(6), 223-237.

Ely, D. P. (1992). *Trends in educational technology*: New York: Syracuse. ERIC Document Number: 346850.

Erbaş, K., A. (2005). Çoklu gösterimlerle problem çözme ve teknolojinin rolü. *TOJET, 4*(4), 88-92.

Erkuş, A. (2003). *Psikometri üzerine yazılar.* Ankara: Türk Psikologlar Derneği Yayınları. No:24.

FATİH. (no date). Eğitimde FATİH projesi hakkında. Retrieved March 5, 2017, from http://fatihprojesi.meb.gov.tr/proje-hakkinda/

Field, A. (2009). *Disccovering statistics using SPSS*. London: Sage.

Graham, C. R., Borup, J., & Smith, N. B. (2012). Using TPACK as a framework to understand teacher candidates' technology integration decisions. *Journal of Computer Assisted Learning, 28*, 530-546.

Gudmundsdottir, S., & Shulman, L. S. (1987). Pedagogical content knowledge in social studies. *Scandinavian Journal of Educational Research, 31*(2), 59-70. doi: 10.1080/0031383870310201

Howey, K. R., & Grossman, P. L. (1989). A study in contrast: Sources of pedagogical content knowledge for secondary English. *Journal of Teacher Education, 40*(5), 24-31.

Koehler, M., Shin, T. S., & Mishra, P. (2012). How do we measure TPACK? Let me count the ways. In R. N. Ronau, C. R. Rakes & M. L. Niess (Eds.), *Educational technology, teacher knowledge, and classroom impact* (pp. 16-31). Hershey, PA: Information Science Reference.

Koh, J. H.-L., Chai, C.-S., & Tsai, C.-C. (2010). Examining technological pedagogical content knowledge of Singapore pre-service teachers with a large-scale survey. *Journal of Computer Assisted Learning, 26*(6), 563-573.

Koh, J. H. L., Chai, C. S., & Tsai, C. C. (2014). Demographic factors, TPACK constructs, and teachers' perceptions of constructivist-oriented TPACK. *Educational Technology & Society, 17*(1), 185–196.

Lawless, K. A., & Pellegrino, J. W. (2007). Professional development in integrating technology in teaching and learning: Knowns, unknowns and ways to pursue better questions and answers. *Review of Educational Research, 77*(4), 575-614.

Liu, Q., Zhang, S., & Wang, Q. (2015). Surveying Chinese in-service K12 teachers' technology, pedagogy, and content knowledge. *Journal of Educational Computing Research, 53*(1), 55-74.

Macaro, E., Handley, Z., & Walter, C. (2012). A systematic review of CALL in English as a second language: Focus on primary and secondary education. *Language Teaching, 45*(1), 1-43.

Marks, R. (1990). Pedagogical content knowledge: From a mathematical case to a modified conception. *Journal of Teacher Education, 41*(3), 3-11.

McEwan, H., & Bull, B. (1991). The pedagogic nature of subject matter knowledge. *American Educational Research Journal, 28*(2), 316-334.

MEB. (2009a). *İlköğretim matematik dersi (1-5. sınıflar) öğretim programı,* Ankara: Devlet Kitapları Müdürlüğü.

MEB. (2009b). *İlköğretim matematik dersi (6-8. sınıflar) öğretim programı ve kılavuzu,* Ankara: Devlet Kitapları Müdürlüğü Basımevi.

MEB. (2011). *Ortaöğretim matematik (9-12. sınıflar) dersi öğretim programı,* Ankara: Devlet Kitapları Müdürlüğü Basımevi.

MEB. (2015). *İlkokul matematik dersi 1-4. sınıflar öğretim programı*. Ankara: MEB – Talim Terbiye Kurulu Başkanlığı Yayıncılık.

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

Özgelen, S. (2013). Fen ve matematik eğitiminde teknolojik pedagojik alan bilgisi temelli öğretim tasarımları. In T. Yanpar-Yelken, H. Sancar-Tokmak, S. Özgelen & L. İncikabı (Eds.), *Fen ve teknoloji öğretmen adaylarının teknolojik pedagojik alan bilgilerinin bloglar yardımıyla tasarlanan bilimin doğası dersinde geliştirilmesi* (1. Baskı): Ankara: Anı Yayıncılık.

Öztürk , E., & Horzum, M. B. (2011). Adaptation of technological pedagogical content knowledge scale to Turkish. *Ahi Evran Üniversitesi Eğitim Fakültesi Dergisi, 12* (3), 255-278.

Powers, R., & Blubaugh, W. (2005). Technology in mathematics education: Preparing teachers for the future. *Contemporary Issues in Technology and Teacher Education, 5*(3/4), 254-270.

Sang, G., Tondeur, J., Chai, C.-S., & Y., D. (2016). Validation and profile of Chinese pre-service teachers' technological pedagogical content knowledge scale. *Asia-Pacific Journal of Teacher Education, 44*(1), 49-65.

Sarı, M.H., & Özerbaş, M.A. (2013). *Sınıf öğretmenlerinin ilkokul matematik öğretiminde teknoloji kullanımına ilişkin algılarının belirlenmesi.* 12. Ulusal Sınıf Öğretmenliği Sempozyumu [Tam Metin Basım], 23-25 Mayıs 2013 Adnan Menderes Üniversitesi, Aydın.

Sarı, M.H., & Akbaba-Altun, S. (2015). Sınıf öğretmenlerinin matematik öğretiminde teknoloji kullanımı üzerine nitel bir araştırma. *International Journal of Eurasia Social Sciences, 6*(19)*,* 24-49.

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

Segall, A. (2004). Revisiting pedagogical content knowledge: The pedagogy of content/the content of pedagogy. *Teaching and Teacher Education, 20*(5), 489-504.

Shinas, V. H., Yilmaz-Ozden, S., Mouza, M., Karchmer-Klein, M., & Glutting, J. J. (2013). Examining domains of technological pedagogical content knowledge using factor analysis. *Journal of Research on Technology in Education, 45*(4), 339-360.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-21.

Simon, R. I. (1992). *Teaching against the grain: Texts for a pedagogy of possibility*. New York: Bergin & Garve.

Smith, D. C., & Neale, D. C. (1989). The construction of subject matter knowledge in primary science teaching. *Teaching & Teacher Education, 5*(1), 1-20.

Su, X., Huang, X., Zhou, C., & Chang, M. (in press). A technological pedagogical content knowledge (TPACK) scale for geography teachers in senior high school. *Science and Education, Early release*, 1-17. doi: 10.15390/EB.2017.6849

Şencan, H. (2005). *Sosyal ve davranışsal ölçümlerde güvenirlik ve geçerlilik. (Birinci Baskı).* Ankara: Seçkin Yayıncılık.

Şimşek, Ö.F. (2007). Y*apısal eşitlik modellemesine giriş, temel ilkeler ve LİSREL uygulamaları.* Ankara: Ekinoks Yayınları.

Tavşancıl, E. (2005). *Tutumların ölçülmesi ve spss ile veri analizi. (Üçüncü Baskı).* Ankara: Nobel Yayıncılık.

Tezci, E., & Perkmen, S. (2013). Oluşturmacı perspektiften teknolojinin öğrenme-öğretme sürecine entegrasyonu. In K. Çağıltay & Y. Göktaş (Eds.), *Öğretim teknolojilerinin temelleri: Teoriler, araştırmalar, eğilimler* (1. Baskı): Ankara: Pegem Akademi.

Turkish Board of Educcation. (no date). Öğretim programları Retrieved April 1, 2017, from http://ttkb.meb.gov.tr/program2.aspx

Voogt, J., Fisser, P., Roblin, N. P., Tondeur, J., & van Braak, J. (2012). Technological pedagogical content knowledge- a review of literature. *Journal of Computer Assisted Learning, 29*, 109-121.

Zelkowski, J., Gleason, J., Cox, D. C., & Bismarck, S. (2013). Developing and validating a reliable TPACK instrument for secondary mathematics preservice teachers. *Journal of Research on Technology in Education, 46*(2), 173-206.