

Examination of the Relationship between TPACK Competencies and Mathematics Teaching Anxiety: The Mediating Role of Mathematics Anxiety

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Abstract:

This study explored the mediating role of mathematics anxiety in the relationship between TPACK competencies and mathematics teaching anxiety. This mediation role was tested through structural equation modeling using data from 426 pre-service mathematics teachers selected through criterion sampling. TPACK Competencies Scale, Mathematics Anxiety Scale, and Mathematics Teaching Anxiety Scale were used to collect data. The data were analyzed through descriptive statistics, correlation analysis and path analysis. The study revealed a negative relationship between TPACK competencies and mathematics anxiety, and mathematics teaching anxiety, while there was a positive relationship between mathematics anxiety and mathematics teaching anxiety. The results suggested that the pre-service teachers' mathematics anxiety had a mediating role in accounting for the relationship between TPACK competencies and mathematics teaching anxiety. Additionally, TPACK competencies explained 69% of the total variance in mathematics teaching anxiety through mathematics anxiety in the structural equation model. The study argued that offering pre-service teachers technology-supported education during undergraduate education may develop their TPACK competencies and reduce their mathematics anxiety and teaching anxiety.

Keywords:

TPACK, Mathematics anxiety, Mathematics teaching anxiety, Structural equation modeling

Citation:

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INTRODUCTION

Mathematics researchers have focused on the factors affecting mathematics teaching anxiety in the last two decades. The literature highlights that mathematics teaching anxiety has negative or positive links with several factors, including mathematics anxiety (Hacıömeroğlu, 2014; Peker & Ertekin, 2011; Vinson, 2001; Wilson, 2013, Yazlık & Çetin, 2020; Olson & Stoehr, 2021), deficiency in content knowledge (Hoşşirin, 2010; Peker, 2006), self-efficacy perception regarding mathematics (Ural, 2015), attitudes towards technology use (Tatar et al., 2015), beliefs towards mathematics teaching (Başpınar & Peker, 2016), problem-solving skill (Akinsola, 2008), and self-efficacy perception regarding mathematics teaching (Deringöl, 2018; Peker, 2016). Among these variables, mathematics anxiety stands out since it is another anxiety type experienced directly in mathematics teaching. Though a consensus on the relationship between mathematics anxiety and mathematics teaching anxiety has not been established yet, studies report positive relationships between the two anxiety types (Peker & Ertekin, 2011; Serin, 2017; Yazlık & Çetin, 2020). Besides, several studies investigate the reasons for both anxiety types (Ameen et al., 2002; Nolting, 2010; Peker, 2008; Wilson, 2013). Technology integration into mathematics education, particularly in the last two decades, is expected to decrease mathematics anxiety and mathematics teaching anxiety of both teachers and pre-service teachers (Gökoğlu-Uçar & Ertekin, 2019; Zengin, 2017). However, the literature lacks adequate studies exploring the relationships between Technological Pedagogical Content Knowledge (TPACK), which is one of the technology competencies that teachers and pre-service teachers should have, and both mathematics anxiety and mathematics teaching anxiety. This deficiency indicates a need for more studies to understand the nature of these relationships better.

The literature on TPACK and mathematics teaching anxiety embodies experimental studies reporting that learning environments supported with technology reduced pre-service teachers' mathematics teaching anxiety. It was observed that using activities designed with WebQuest (Peker & Halat, 2009) and GeoGebra software (Zengin, 2017) reduced pre-service teachers' mathematics teaching anxiety. However, the number of studies examining the relationship between technology and mathematics teaching anxiety is limited. Some studies examined the relationship between pre-service mathematics teachers' mathematics teaching anxiety and their perceptions of technology use in mathematics teaching (Tatar et al., 2015) and TPACK competencies (Gökoğlu-Uçar & Ertekin, 2019). Furthermore, some other studies reported reduced mathematics anxiety in students using technology. In their meta-analysis study, Sun and Pyzdrowski (2009) found that using technology devices in mathematics lessons lessened students' mathematics anxiety. Besides, content-based and technology-supported tasks (Juniati & Budayasa, 2021; Carjuzza & Williams, 2021) and learning experiences designed with Geogebra (Zengin, 2017) reduced mathematics anxiety. Finally, to the researchers' best knowledge, no studies examine the relationship between TPACK and mathematics anxiety. Except for experimental studies, the studies involve regression analysis exploring the relationships

among these variables, revealing a niche in studies that comprehensively address the relationships among TPACK competencies, mathematics anxiety, and mathematics teaching anxiety. Experimental and regression studies examine the relationships among these variables; however, no structural equation modeling study addresses the relationships among TPACK competencies, mathematics anxiety, and mathematics teaching anxiety holistically.

This study focused on the relationship between mathematics pre-service teachers' mathematics anxiety and the practices related to technology integration used in teacher training programs to improve their mathematics and mathematics teaching anxiety. Additionally, the literature review does not host studies revealing the relationships among these three variables clearly, and mathematics anxiety is an undeniable variable in the relationship between TPACK and mathematics teaching anxiety. Accordingly, the current study attempted to investigate the mediating role of mathematics anxiety in the relationship between TPACK and mathematics teaching anxiety. Thus, the current study aimed to explore the mediating role of mathematics anxiety in the relationship between TPACK competencies and mathematics teaching anxiety. To this end, this study employed structural equation modeling, which has certain advantages over regression analysis in that it includes measurement errors and identifies direct and indirect relations among variables. Given that these three variables interact strongly in learning environments, an examination of pre-service teachers in this respect is expected to contribute to the literature.

Theoretical Framework

Mathematics Teaching Anxiety

Mathematics teaching anxiety refers to anxiety and tension teachers experience while teaching mathematical concepts, theorems, and formulas or during the problem-solving process (Levine, 1993; Peker, 2006). This type of anxiety may arise in organizing the learning environment, time management, and identifying teaching methods and learning activities (Ameen et al., 2002; Peker, 2009a). Teachers experiencing mathematics teaching anxiety are reported to demonstrate reactions such as tension, inability to concentrate, being easily distracted, not hearing the students, sweating hands, and talking to oneself negatively (Levine, 1993). This type of anxiety teachers undergo affects the experiences of mathematics teaching, thereby negatively affecting students' mathematics learning. Therefore, some studies examined teachers' and pre-service teachers' levels of mathematics teaching anxiety in terms of grade and gender (Çenberci, 2019; Demir et al., 2016; Tatar et al., 2016; Yavuz, 2018). Additionally, some other studies addressed the reasons for mathematics teaching anxiety (Ameen et al., 2002; Huber & Ward, 1969; Peker, 2008). Some of these reasons include the challenges the students experience in solving questions, high expectations of being a good mathematics teacher, and the increased need for finding concrete materials.

Mathematics anxiety is another type of anxiety that teachers may experience apart from mathematics teaching anxiety. Different from mathematics anxiety, mathematics

teaching anxiety is experienced by teachers while teaching mathematics. On the other hand, mathematics anxiety is the type of anxiety felt when solving any mathematics problem. Hence, while only teachers can experience mathematics teaching anxiety, all people learning mathematics may experience mathematics anxiety. Mathematics anxiety is addressed in detail below.

Mathematics Anxiety

Students mostly regard mathematics as a lesson that consists of only numbers and calculations and involves a set of rules (Markovits & Forgasz, 2017; Van de Walle, 2004; Yetim-Karaca & Ada, 2018). Students generally find mathematics difficult and think they may fail mathematics lessons (Kayan & Çakiroğlu, 2008; Üredi & Üredi, 2005). In addition, it is reported that these negative attitudes toward mathematics increase as the students move on school grades, and mathematics becomes a nightmare for some students (Baykul, 2016; Ma & Xu, 2004). On the other hand, these negative attitudes are not limited to students; they also apply to adults, pre-service teachers, and teachers (Hembree, 1990; Katipoğlu & Öncü, 2015; Lim & Ernest, 1999; Şenol et al., 2015). It is reported that these negative feelings towards mathematics in the society affect negative attitudes towards mathematics and lead to the development of mathematics anxiety in particularly students (Baloğlu, 2001; Deringöl, 2018; Özdemir & Gür, 2011; Yenilmez, 2010).

Mathematics anxiety has various definitions in the literature. These definitions suggest that mathematics anxiety causes psychological responses in students such as concern, tension, fear, panic, and irritability while solving maths problems (Dreger & Aiken, 1957; Miller & Mitchell, 1994). As well as psychological responses, mathematics anxiety causes physical responses such as palm sweating, heart palpitations, and nausea (Ashcraft & Krause, 2007; Ashcraft, 2002; Baloğlu & Koçak, 2006). These results suggest that mathematics anxiety is one of the most critical factors restraining students' learning of mathematics (Bai, 2011; Cates & Rhymer, 2003). In support of this notion, studies in the literature highlight that mathematics anxiety negatively affects students' academic achievement (Ader, 2004; Al-Mutawah, 2015; Bayırlı et al., 2021; Ho et al., 2000; Ma & Xu, 2004). Additionally, mathematics anxiety is reported to decrease students' interest in mathematics lessons (Keitel & Kilpatrick, 2005; Sherman & Wither, 2003; Zakaria & Nordin, 2008) and self-confidence (Aydın, 2011; Bursal & Paznokas, 2006; Olatunde, 2009).

The studies on the reasons for mathematics anxiety that negatively affect students' learning in various ways report several factors affecting the emergence of mathematics anxiety. The reasons for mathematics anxiety are peculiar to individuals because it is a learned anxiety type (Nolting, 2010., Wilson, 2013). These reasons are also affected by the nature of mathematics and the methods used in mathematics teaching (Baloğlu, 2001; Peker, 2006). As well as the methods and techniques teachers use, their characters and attitudes towards lessons and students are also effective in mathematics anxiety (Swanson & Nebraska, 2006). Studies reported that students who had earlier negative experiences with

their mathematics teachers were anxious about mathematics and the effects of this negative experience with their teachers went down over a very long time (Bekdemir et al., 2004; Perry, 2004). Hence, we can argue that teachers' attitudes towards mathematics and mathematics teaching and their professional competencies critically affect students' mathematics anxiety. However, research revealed that teachers (Baloğlu, 2001) and pre-service teachers (Bekdemir, 2010) also experience mathematics anxiety, and teachers transfer the mathematics anxiety they undergo to their students in conscious or unconscious ways (Baloğlu, 2001; Vinson, 2001). Therefore, it is critical to examine the variables related to pre-service teachers' mathematics anxiety in the pre-service period and eliminate their mathematics anxiety by controlling these variables.

TPACK

With the recent technological advances, the use of technology in learning-teaching experiences has become necessary (Hew & Brush, 2007). This has led to changes in the knowledge and competencies that teachers should possess in the last two decades. Teachers are now expected to have technology knowledge and integrate technology into their lessons (Graham et al., 2012). Therefore, the technological aspect was added to Shulman's (1986) Pedagogical Content Knowledge (PCK), Technological Pedagogical Content Knowledge (TPACK) framework was developed (Mishra & Koehler, 2006). TPACK is considered as a model explaining what teachers should know to efficiently integrate technology into their teaching fields (Schmidt et al., 2009). In this model, there are seven knowledge types, which are Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge and their combinations which are Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006). The components of TPACK are presented in Figure 1.

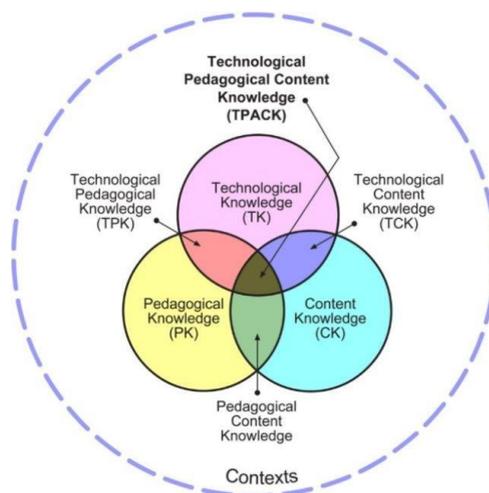


Figure 1. Components of TPACK Model

The knowledge types in TPACK model can be briefly explained as follows: CK refers to knowledge of the field that is to be taught; PK refers to knowledge regarding methods and practices employed during the learning-teaching process; and TK includes the

knowledge needed for using digital technologies such as multimedia, interactive board, and the internet as well as other advanced technologies. Additionally, PCK refers to the knowledge about selecting the best method for the content knowledge and teaching that subject in the best way. TCK relates to the knowledge for integrating technology with the field and using the most appropriate technology for the content knowledge. TPK appertains to the knowledge on technologies developed to be used in instruction as well as using appropriate technologies for teaching methods. Finally, TPACK refers to the knowledge on how to integrate technology and teaching methods while teaching a subject, and how technological tools and presentations affect students' grasping the contents (Angeli & Valanides, 2009; Graham et al., 2012; Mishra & Koehler, 2006; Koehler & Mishra, 2009).

As the above explanations suggest, teachers are expected to use technology by blending it with the pedagogic perspective that is appropriate for the learning outcomes of the lesson (Demir et al., 2011; Ertmer & Ottenbreit-Leftwich, 2010; Şad & Göktaş, 2014). However, it is difficult for teachers to integrate technology into their teaching practices (Jang & Tsai, 2012). The studies in the literature reported that teachers could not effectively use technology in the classroom. However, they generally made use of technology to carry out tasks assigned to them by the administration, communicate via e-mails, prepare plans, prepare for lessons and write examination questions (Erdemir et al., 2009; Sancar-Tokmak et al., 2012; Yanpar-Yelken et al., 2013). This demonstrates the significance of training teachers who can integrate technology into their fields in teacher training programs. Therefore, it is critical to carry out practices in teacher training programs that would enable pre-service teachers to enhance their TPACK levels (Abbitt & Klett, 2007).

That TPACK has recently become a commonly referred framework in training pre-service teachers and teacher competencies (Niess, 2012) has resulted in studies towards identifying teachers' and pre-service teachers' TPACK levels (Alayyar et al., 2012; Archambault & Barnett, 2010; Timur & Taşar, 2011b; Çetin, 2017). However, the TPACK framework is focused on knowledge level, and it is hard to directly measure teachers' and pre-service teachers' knowledge levels, which directed researchers conducting studies on how teachers and pre-service teachers perceived their TPACK levels (Açıkgül & Aslaner, 2015). This is evident in the fact that studies in the literature mainly examined teachers and pre-service teachers' perceptions of their competence regarding TPACK (Balçın & Ergün, 2018; Kaya et al., 2011; Şad et al., 2015) and self-confidence (Graham et al., 2012; Saltan & Arslan, 2017; Sancar-Tokmak et al., 2013) in terms of various variables. Additionally, some studies explore the relationships between pre-service mathematics teachers' TPACK competencies and their thinking styles (Canbolat et al., 2016), perceptions of technology use frequency (Özgen et al., 2013), and mathematics teachers' TPACK competencies and their teaching style preferences (Mutluoğlu & Erdoğan, 2016), and their attitudes towards information and communication technologies (Albayrak-Sarı et al., 2016). However, few studies examined the relationship between TPACK competencies, mathematics anxiety, and mathematics teaching anxiety (Gökoğlu-Uçar & Ertekin, 2019).

Conceptual Framework

Factors such as negative attitudes towards mathematics, deficiency in content knowledge, and self-confidence affect pre-service teachers' mathematics anxiety and mathematics teaching anxiety (Peker, 2006). Recently, efforts have been invested in teacher training institutions to develop pre-service teachers' not only content knowledge solely but also their TPACK levels comprehensively. It is thought that pre-service teachers who can use technology in line with the course aims with the appropriate pedagogy and feel competent in these respects would have low mathematics teaching anxiety. Therefore, this study hypothesizes a negative relationship between TPACK competencies and mathematics teaching anxiety (H₁). In addition, it is assumed that when pre-service teachers' TPACK competencies are enhanced, their mathematics anxiety will decrease. In the same vein, studies in the literature found that computer-supported mathematics instruction lessened students' mathematics anxiety (Sun & Pyzdrowski, 2009). Similarly, the technology-supported education offered in education faculties enables meaningful learning thanks to technological opportunities and improves their content knowledge (Çetin, 2017) which can also be interpreted that this improvement reduces pre-service teachers' mathematics anxiety. Therefore, the study's second hypothesis assumes a negative relationship between TPACK competencies and mathematics anxiety (H₂).

Teachers with high levels of mathematics anxiety are reported to use traditional teaching methods more frequently and focus on teaching basic skills as opposed to teaching concepts (Gresham, 2010; Swars et al., 2006). Accordingly, we can suggest that teachers experiencing mathematics anxiety may have negative attitudes towards mathematics teaching. Due to their mathematics anxiety, teachers may experience problems in teaching mathematics to students and therefore experience mathematics teaching anxiety. The literature also supports this notion with the findings that the mathematics anxiety teachers experience transforms into mathematics teaching anxiety (Hadley & Dorward, 2011). Additionally, mathematics anxiety is a significant predictor of mathematics teaching anxiety for also pre-service teachers (Hacıömeroğlu, 2014; Peker & Ertekin, 2011; Serin, 2017; Yazlık & Çetin, 2020). We can again argue that mathematics anxiety is related to pre-service teachers' mathematics teaching anxiety, hindering them from enhancing their mathematics teaching competencies.

On the other hand, it was also reported that the relationship between pre-service primary school teachers' mathematics anxiety and mathematics teaching anxiety was not always significant, and pre-service teachers with high mathematics anxiety could have low levels of mathematics teaching anxiety (Brown et al., 2011). As these results show, the relationship between mathematics anxiety and mathematics teaching anxiety is not well-established. The literature suggests that pre-service teachers experiencing mathematics anxiety are also expected to experience mathematics teaching anxiety. However, we cannot argue this notion for sure. This can be accounted for by the fact that pre-service teachers

who do not experience mathematics anxiety-or perceive themselves as qualified- may not know how to teach secondary school mathematics to young children. In other words, they may experience mathematics teaching anxiety due to their deficiencies in pedagogical content knowledge. Additionally, pre-service mathematics teachers who experience mathematics anxiety may not experience mathematics teaching anxiety because they may have mathematics anxiety for advanced mathematics subjects and may not have anxiety for secondary school mathematics subjects. Therefore, this study aimed to question the assumption that pre-service teachers' mathematics anxiety predicts their mathematics teaching anxiety (H_3).

Although some studies examining the relationship between mathematics anxiety and mathematics teaching anxiety are present in the literature, there are limited studies examining the relationship between TPACK and mathematics teaching anxiety. There are no regression studies on the relationship between TPACK and mathematics anxiety. However, mathematics anxiety is an unignorable variable while examining the relationship between TPACK and mathematics teaching anxiety, and this gap is a limitation in explaining this relationship. The current study formed the structural model in Figure 2 to fill this niche and clearly reveal the relationships among these variables. This study assumes that mathematics anxiety mediates the relationship between TPACK competencies and mathematics teaching anxiety. In other words, it is assumed that when pre-service teachers' levels of TPACK competencies increase, their mathematics teaching anxiety will decrease since their mathematics anxiety will decrease (H_4). In this sense, the hypotheses are tested through the established structural model (Figure 2).

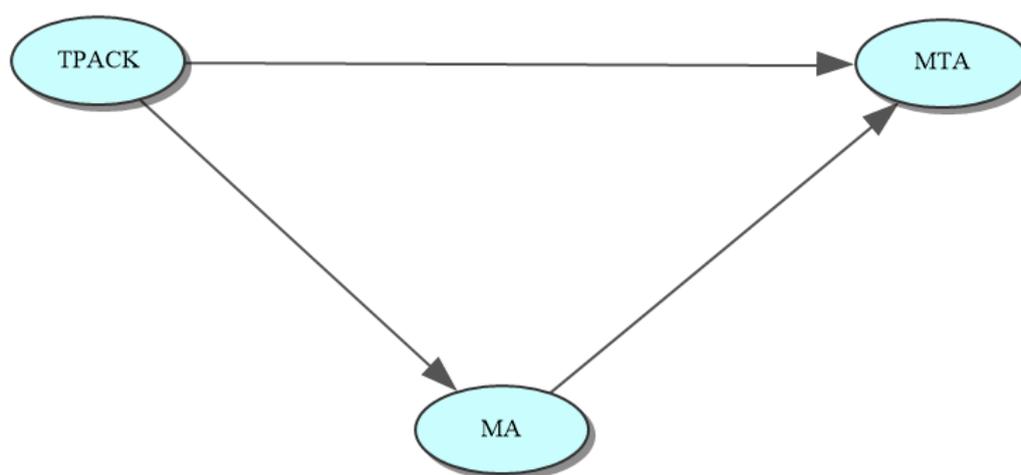


Figure 2. The Research Model

H_1 : TPACK competencies are negatively correlated with mathematics teaching anxiety.

H_2 : TPACK competencies are negatively correlated with mathematics anxiety.

H₃: Mathematics anxiety is positively correlated with mathematics teaching anxiety.

H₄: Mathematics anxiety mediates the relationship between TPACK competencies and mathematics teaching anxiety.

METHOD

Research Design

This study aimed to reveal the relationships among the variables of pre-service mathematics teachers' TPACK competencies, mathematics anxiety, and mathematics teaching anxiety. It was hypothesized that TPACK affects mathematics teaching anxiety, and mathematics anxiety has a mediating role in this relationship. Therefore, this study employed the causal survey design in testing the multiple causal relationships and performed Structural Equation Modeling (SEM). This model aims to determine the co-change between two or more variables within the reason-result framework (Karasar, 2005; Robson, 2015). SEM is a robust statistical analysis method that develops theories by testing the causal relationships between observed and latent variables and simultaneously examining the relationships between multiple variables (Byrne, 2010, Fraenkel et al., 2012). SEM also allows for obtaining more reliable results than regression and path analysis, as it calculates linear relations between variables without error (Meydan & Şeşen, 2011).

Participants

SEM generally requires samples larger than $n=200$ to test hypothesized relationships significantly with the slightest measurement error (Kline, 2011). Hence, 426 pre-service mathematics teachers attending to third and fourth grades of the mathematics teaching program in three education faculties of two universities in Middle Anatolia, Turkey, participated in this study. The criterion sampling method was used in sample selection. The criterion was taking most of the content knowledge courses such as Analysis, Geometry, Algebra, Statistics-Probability Instruction, and Computer Supported Mathematics Teaching, which are needed for pre-service teachers to integrate technology into teaching practices. Since the study was conducted towards the end of the 2020-2021 academic year's spring semester, the participants could take the courses with TPACK competencies and field courses. The researchers asked the pre-service teachers in these universities to fill in the scales through Google Forms. Table 1 presents the distribution of the participants in terms of grade and gender.

Table 1*Distribution of the Participants in terms of Grade and Gender*

	Grade		Total
	3 rd grade	4 th grade	
Female	165	179	344
	47,9%	52,1%	100%
Male	83,8%	78,2%	80,7%
	32	50	82
Total	39,1%	60,9%	100%
	16,2%	21,8%	19,3%
Total	197	229	426
	46,2%	53,8%	100%
	100%	100%	100%

As seen in Table 1, 46.2% of the participants were in third grade (n=197), and 53.8% were in fourth grade (n=229). 80.7% of the participants were female (n=344) and 19.3% were male (n=82).

Instruments

Three scales were used to collect data in this study. The scales are explained below.

Mathematics Anxiety Scale

The scale was developed by Üldaş (2005) to identify teachers' and pre-service teachers' anxiety towards mathematics. The scale was in four-point Likert type (1=I am not anxious, 4= I am quite anxious), and the 39 items in the scale were gathered under seven factors. The factors are 'understanding mathematics anxiety' (UMA), 'discussing mathematics anxiety' (DMA), 'problem-solving anxiety' (PSA), 'arithmetical computation anxiety' (ACA), 'mathematical self-adequacy anxiety' (MSAA), 'mathematical interpretation anxiety' (MIA), and 'making mathematical mistakes anxiety' (MMMA). Üldaş (2005) reported the Cronbach's Alpha reliability coefficient as 0.95; similarly, it was also calculated as 0.95 in the current study. While the minimum score is 39, the maximum score is 156. All the items in the scale are positive; therefore, a higher score on the scale means higher levels of mathematics anxiety. For scale's validity, exploratory factor analysis was performed, and the factor loadings of the items varied between .435 and .801, which explained 59.23% of the total variance.

Mathematics Teaching Anxiety Scale

The scale was developed by Peker (2006) to identify mathematics and primary school pre-service teachers' levels of mathematics teaching anxiety. The scale has 23 items with four factors in a five-point Likert format (1= I definitely agree, 5= I definitely disagree). The scale factors are content knowledge-related anxiety (CKA), self-confidence-related anxiety (SCA),

attitude towards mathematics teaching-related anxiety (AMTA), and pedagogical content knowledge related anxiety (PCKA). Peker (2006) reported the Cronbach's Alpha value of the scale as 0.91, which was calculated as 0.90 in the current study. While the maximum score is 115, the minimum score is 23. Higher scores in the scale refer to higher levels of mathematics teaching anxiety in pre-service teachers. The first ten items are reverse-coded. The exploratory factor analysis for the validity of the scale showed that the factor loadings of the 23 items in the scale range between .528 and .857, accounting for 56.5% of the total variance.

Technological Pedagogical Content Knowledge Scale

The scale, developed by Önal (2016), identifies pre-service mathematics teachers' TPACK competencies. 59 items in the five-point Likert type (5= I am totally competent, 1= I am totally incompetent) gather under nine factors in the scale. The factors include technological knowledge (TK), content knowledge (CnK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), online and offline technological pedagogical knowledge (TPK), technological pedagogical content knowledge (TPCK), and context knowledge (CxK). This study combined online and offline TPK, and the scale was analyzed in eight factors. While the maximum score is 295, the minimum score is 59. There are no reverse-coded items in the scale. Higher scores in the scale mean higher levels of TPACK competencies in pre-service teachers. Önal (2016) reported the Cronbach's Alpha value of the scale as 0.97, which was calculated as the same value in the current study. The exploratory factor analysis for the validity of the scale showed that the factor loadings of the 59 items in the scale range between .495 and .797, accounting for 66.2% of the total variance.

Data Collection

The pre-service mathematics teachers were first informed about the purpose of the research. Then volunteering 458 participants took the instruments through Google forms due to the Covid-19 pandemics conditions. To prevent common method bias, data should either be collected from different sources or data regarding dependent, independent, and mediator variables should be collected at different times when different sources are unavailable (Podsakoff et al., 2003). Since the same participants completed all three scales, the scales were sent to the participants at one-week intervals. The pre-service teachers had five days to complete each scale. The participants spent adequate time filling in the scales. 32 scale forms were excluded from the analysis as they were completed randomly or outliers.

Data Analysis

The data analysis started with descriptive statistics regarding the instruments. The results are presented in Table 2.

Table 2

Distribution of the Participants in terms of Grade and Gender

Variable	Min-Max	X	Sd	Skewness	Kurtosis	Correlation		
						1	2	3
1-Mathematics Anxiety	39 – 110	68.96	14.39	.247	-.429	1	.599	-.422
2-Mathematics Teaching Anxiety	24-76	44.54	11.50	.502	-.324		1	-.449
3-TPACK overall	139-295	216.82	30.07	-.057	-.084			1

Table 2 demonstrates that means of all variables in the model were above the midpoints of the related score ranges, and these values ranged between 44.54 and 216.82. In order to assume univariate normality for the data, the skewness and kurtosis values of the variables should not be greater than |3.0| and |10.0|, respectively (Kline, 2011). The Skewness values ranged between -.001 and -.847, and the Kurtosis values ranged between -.243 and .615, indicating that univariate normality for the data was met. Mahalanobis distance was checked for multi-variate normality, and tolerance and VIF values were checked for multicollinearity. Mahalanobis distance value was calculated, and 32 significant ($p=.01$) outlier values were identified. Since the sample was large enough, these values were excluded from the analysis. The correlation coefficients among the observed variables were not very high. The tolerance value was larger than 0.20, and the VIF value was smaller than 10, meeting the multicollinearity assumption (Field, 2009; Montgomery & Peck, 1992). Hence, the problem of multicollinearity was not present in the analysis.

Path analyses were performed on AMOS involving the measurement and structural model to test the model's fitness with the data. The ratio of chi-square to the degree of freedom (χ^2/df), root mean square error of approximation (RMSEA), standardized root mean square residual (SRMR), normed fit index (NFI), non-normed fit index (TLI), and comparative fit index (CFI) were checked for the fit of SEM models (Çelik & Yılmaz, 2013; Kline, 2011; Schumacker & Lomax, 2010). The criterion values for fit indices are provided in detail in Table 3. To enhance the fit index values regarding the model in SEM analyses, modifications (error binding) that were supported theoretically were conducted. After each error binding, the χ^2 difference test was conducted, and the new model was compared with the previous model in terms of fit indices and significance of the chi-square test. To test H4, the mediating role of the mediator variable (mathematics anxiety) between the independent variable (TPACK) and the dependent variable (mathematics teaching anxiety) was checked. The following three assumptions should be met before performing mediation analysis (Baron & Kenny, 1986; MacKinnon et al., 2007). First, the independent variable should predict the dependent variable directly and significantly. Second, there should be a linear regression relationship between the independent and mediating variables. Third, to reveal

the mediating role in the mediator model, there should be some decrease (absolute value) in the relationship between dependent and independent variables when the effect of the mediating variable is controlled.

Yılmaz and İlhan-Dalbudak (2018) argue that the mediating variable may explain the whole or only a part of the observed relationship between dependent and independent variables. It is called full mediation when the mediator explains the whole relationship, and partial mediation when it explains a part of it. In full mediation, the relationship between dependent and independent variables weakens and becomes statistically insignificant when the mediating variable is included in the analysis. In partial mediation, the mediating variable cannot measure the whole relationship between the dependent and independent variables. Although the relationship between the dependent and independent variables is still significant, there is a decrease in the effect coefficient and significance level. To test the statistical significance of the indirect effect of TPACK competency on mathematics teaching anxiety through mathematics anxiety, a bias-corrected bootstrapping procedure was performed on AMOS, as suggested by Preacher and Hayes (2008). The sample size was increased to 5.000, and the 95% confidence interval was ensured. In mediation effect analyses conducted with the Bootstrap technique, the values in 95% confidence interval should not involve zero (0) value to be able to support the research hypothesis (Preacher & Hayes, 2008).

FINDING

Findings Regarding the Measurement Model

Since the data had normal distribution, the covariance matrix was generated using the Maximum Likelihood method. First, the measurement model consisting of the variables of TPACK competencies and mathematics teaching anxiety was tested to test the H1 hypothesis, which assumed that TPACK competencies are negatively correlated with mathematics teaching anxiety (TPACK Competencies → Mathematics Teaching Anxiety). The measurement model is presented in Figure 3. The fit indices calculated in the analysis confirmed the measurement model ($\chi^2[46, n=426] = 169,5; p < .01; \chi^2/df = 3.69; NFI = 0.95, TLI = 0.95, CFI = 0.96; RMSEA = 0.08; SRMR = 0.06$). When the mathematics anxiety was controlled and the regression was performed without the mediator variable, TPACK competencies predicted mathematics teaching anxiety ($\beta = -.57; p < .01$). A one-unit increase in TPACK competencies decreased pre-service teachers' mathematics teaching anxiety by .57 unit. Hence, H₁ was confirmed. TPACK competencies explained 38% of mathematics teaching anxiety.

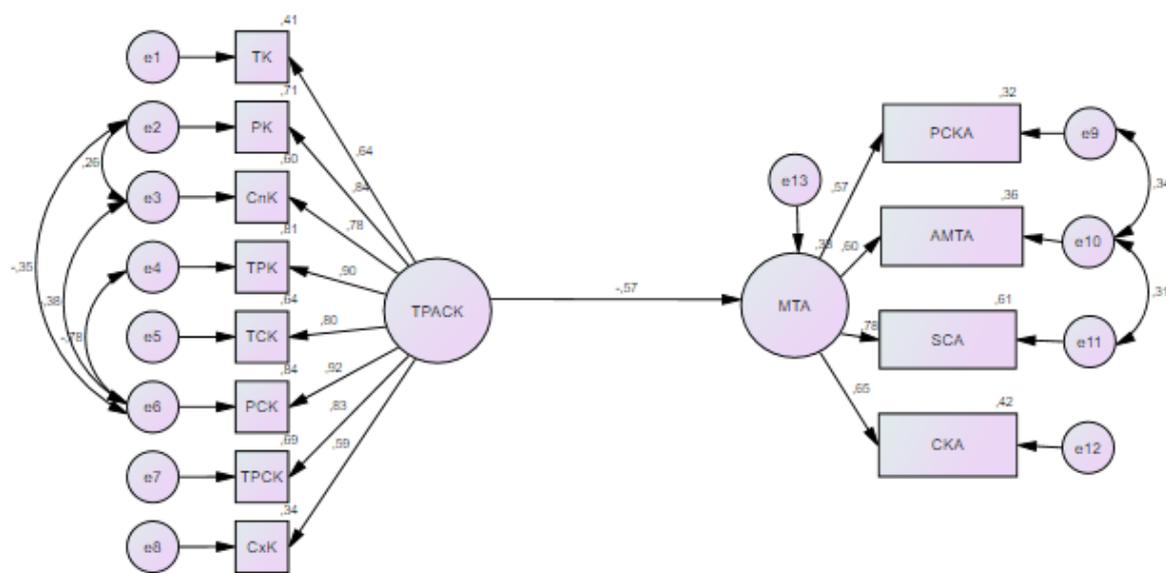


Figure 3. AMOS Screenshot for the Measurement Model

Findings Regarding the Measurement Model

Following the verification of the measurement model, the research hypotheses were tested through the structural model with implicit variables. To test the other hypotheses of the study, a separate model was formed in which mathematics anxiety was the mediator variable. The model is presented in Figure 4.

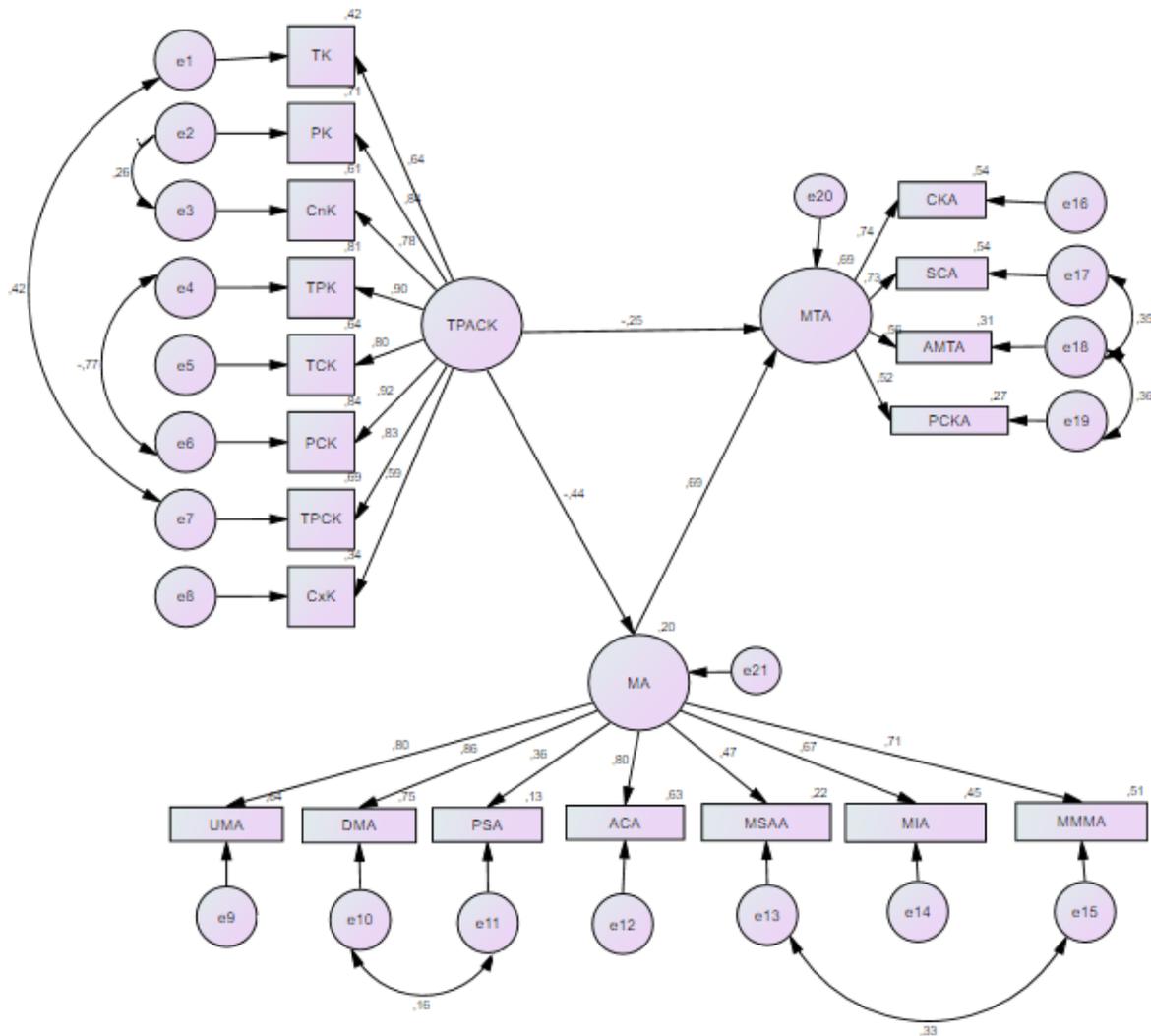


Figure 4. AMOS Screenshot for Structural Model

As Figure 4 demonstrates, the analysis revealed that TPACK competencies predicted mathematics anxiety significantly ($\beta = -.44$; $p < .01$). This indicated that a one-unit increase in TPACK competencies decreased the pre-service teachers' mathematics anxiety by .44 unit. Hence, H_2 (TPACK competencies \rightarrow Mathematics Anxiety) was supported. Similarly, mathematics anxiety, the mediator variable, predicted mathematics teaching anxiety ($\beta = .69$; $p < .01$). Therefore, H_3 (Mathematics Anxiety \rightarrow Mathematics Teaching Anxiety) was accepted. Finally, when mathematics anxiety was added to the model as the mediator variable, the path coefficient from TPACK competencies to mathematics teaching anxiety was still significant ($\beta = -.25$; $p < .01$). The direct effect of TPACK competencies on mathematics teaching anxiety increased significantly from $-.57$ to $-.25$ (decreased in absolute value). Therefore, the model suggested that TPACK competencies affected mathematics teaching anxiety indirectly with the mediation of mathematics anxiety, supporting H_4 . In the model where mathematics anxiety was the mediator variable, TPACK competencies accounted for 69% of the variance in mathematics teaching anxiety. Additionally, the path analysis revealed that the fit indices were within the cut-off values in the literature,

indicating the model fitted to the data and acceptable ($\chi^2[137, n=426] = 401,284$; $p < .01$, $\chi^2/df = 2.92$; $NFI = 0.92$, $TLI = 0.94$, $CFI = 0.95$, $RMSEA = 0.07$; $SRMR = .05$). Fit values regarding the structural model are provided in Table 3.

Table 3

Results Regarding the Structural Model

Measure	Good fit	Acceptable fit	Fit values of the model	
χ^2/df	≤ 3	$\leq 4-5$	3.82	Acceptable fit
RMSEA	≤ 0.05	$\leq 0.06-0.08$	0.07	Acceptable fit
SRMR	≤ 0.05	$\leq 0.05-0.10$	0.05	Good fit
NFI	≥ 0.95	0.94-0.90	0.92	Acceptable fit
IFI	≥ 0.95	0.94-0.90	0.96	Good fit
TLI	≥ 0.95	0.94-0.90	0.94	Acceptable fit
CFI	≥ 0.95	0.94-0.90	0.95	Good fit

Findings Regarding Bootstrapping Analysis

A path analysis based on bootstrapping method was run to test whether there is a mediating role of mathematics anxiety in the relationship between TPACK competencies and mathematics teaching anxiety. In the Bootstrap analysis, the 5000 resampling option was preferred. The analysis showed that the indirect effect of TPACK competencies on mathematics teaching anxiety through mathematics anxiety was significant ($\beta = -.30$, %95 CI [-0.376, -0.220]). Accordingly, it was observed that the Bootstrap lower and upper confidence interval values obtained by the percentage method did not include the value of 0 (zero). These results prove that mathematics anxiety mediates the relationship between TPACK competencies and mathematics teaching anxiety. The results of this analysis are provided in Table 4.

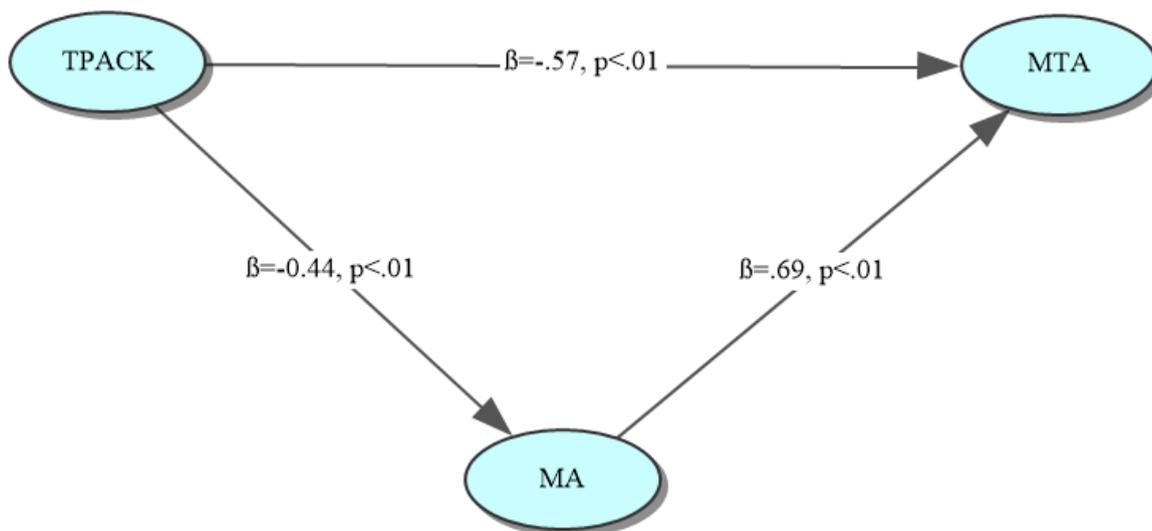
Table 4

Results Regarding the Structural Model Bootstrapping Analysis (n=426)

Variables	Values			
	Mathematics Anxiety		Mathematics Teaching Anxiety	
	β	S.E.	β	S.E.
TPACK (path c)	-	-	-.57*	.026
R ²	-	-	.38	-
TPACK (path a)	-.44*	0.50	-	-
R ²	0.20	-	-	-
TPACK (path c')	-	-	-.25*	.017
Mathematics Anxiety (path b)	-	-	.69*	.029
R ²	-	-	.69	-
Bootstrap Indirect Effect	-	-	-.30* (-0.38, -0.22)	-

Note: * $p < .01$, S.E.=Standard Error; Values in parentheses are lower and upper confidence intervals. Bootstrap resampling=5.000

Concerning the full or partial mediation effect of the mediator variable, it was observed that, in the assumed model, the effect coefficient of TPACK competencies on mathematics teaching anxiety ($\beta = -.25$, $p < .01$) was low but still statistically significant. Therefore, we found that mathematics anxiety had a partial mediating effect in the relationship between TPACK competencies and mathematics teaching anxiety. Figure 5 below shows the results of the model in the study.



Direct Effect $\beta = -0.255$, $p < .05$

Indirect Effect $\beta = -.304^*$ %95 CI (-0.409, -0.146)

Figure 5. Results Regarding the Model in the Study

DISCUSSION AND CONCLUSION

This study revealed a negative relationship between pre-service mathematics teachers' TPACK competencies and their mathematics teaching anxiety. This suggests that the more pre-service mathematics teachers' TPACK competencies increase, the lesser their mathematics teaching anxiety will be. Pre-service mathematics teachers who integrate technology into mathematics teaching and consider themselves adequate in this sense can conduct their courses without experiencing difficulties and tension in teaching mathematics. Similarly, another study reported that sub-dimensions of pre-service mathematics teachers' TPACK competencies negatively predicted sub-dimensions of their mathematics teaching anxiety (Gökoğlu-Uçar & Ertekin, 2019). The competency of PCK, a component of TPACK, also increased mathematics teaching proficiency and hence decreased mathematics teaching anxiety (Aksu & Kul, 2019). These results highlight the significance of carrying out activities to enhance pre-service mathematics teachers' TPACK levels for them to teach mathematics appropriately and effectively. Similarly, experimental studies indicated that learning environments supported with technology decreased pre-service teachers' mathematics teaching anxiety (Peker & Halat, 2009; Zengin, 2017).

Another result of the current study acknowledges a negative relationship between pre-service mathematics teachers' TPACK competencies and mathematics anxiety. This result means that the more TPACK levels of pre-service mathematics teachers increase, and the more they feel competent in this area, the less mathematics anxiety they will experience. The literature tells that lack of content knowledge which is one of the main components of the TPACK model, affects mathematics anxiety (Peker, 2006). Besides, technology-supported mathematics learning environments lessen students' mathematics anxiety (Sun & Pyzdrowski, 2009). It was found that particularly constructing mathematical concepts with the help of Geogebra and activities related to teaching those concepts contributed to decreased mathematics anxiety in pre-service mathematics teachers (Zengin, 2017). Therefore, efforts towards TPACK development of pre-service mathematics teachers in teacher training programs are significant.

The current study also found a positive relationship between mathematics anxiety and mathematics teaching anxiety, indicating that mathematics anxiety affects pre-service teachers' mathematics teaching experiences and hence bringing along mathematics teaching anxiety. The literature lends its support to these results (Hacıömeroğlu, 2014; Hadley & Dorward, 2011; Peker & Ertekin, 2011; Serin, 2017; Yazlık & Çetin, 2020). On the other hand, the relationship between pre-service teachers' mathematics anxiety and mathematics teaching anxiety is not present in every context (Brown et al., 2011). Accordingly, it was found that some of the pre-service teachers experiencing mathematics anxiety did not have mathematics teaching anxiety, while some others not experiencing mathematics anxiety had mathematics teaching anxiety. Although there is no consensus that mathematics anxiety predicts mathematics teaching anxiety, it is critical to identify pre-service teachers' mathematics anxiety levels when they start teacher training programs and control their mathematics anxiety throughout their undergraduate education.

Finally, the current study determined that, when mathematics anxiety was added to the model, TPACK competencies predicted mathematics teaching anxiety indirectly through mathematics anxiety. In other words, mathematics anxiety partially mediated the relationship between TPACK competencies and mathematics teaching anxiety. The direct effect of TPACK competencies on mathematics teaching anxiety was $-.255$, while its indirect effect was $-.304$. TPACK competencies explained 38% of the total variance in mathematics teaching anxiety in the first model, while this rate was 69% in the second model in which mathematics anxiety was added. When mathematics anxiety was added to the analysis, the relationship between TPACK competencies and mathematics teaching anxiety became more salient. In other words, mathematics anxiety mediated while revealing to what extent TPACK competencies predicted mathematics teaching anxiety clearly. This result argues that mathematics anxiety is an unignorable variable in the relationship between TPACK and mathematics teaching anxiety. Accordingly, eliminating pre-service mathematics teachers' anxiety regarding understanding and interpreting mathematics stemming from their previous mathematics experiences with technology-supported learning environments may

reduce their mathematics teaching anxiety. Therefore, it is crucial to identify pre-service mathematics teachers' levels of mathematics anxiety at the onset of their undergraduate education. The anxiety level of pre-service teachers experiencing mathematics anxiety should be lessened, and necessary precautions should be inserted to prevent undergoing mathematics anxiety. Particularly during the training provided for teaching content knowledge, the contents should be associated with daily life, various methods and strategies should be used, and technology should be integrated into this instruction. Using technology, particularly during training on content knowledge, may contribute to pre-service teachers. Thus, we can prevent mathematics anxiety from transforming into mathematics teaching anxiety in the following years.

As highlighted in the above paragraphs, the variable of TPACK competencies contributes to decreasing pre-service mathematics teachers' mathematics anxiety and mathematics teaching anxiety. Accordingly, we can argue that pre-service teachers equipped with TPACK competencies tend to have lower mathematics anxiety and mathematics teaching anxiety. In other words, TPACK competencies should be enhanced to lessen pre-service teachers both types of anxiety. With the changes in the curricula of education faculties in Turkey, the number of courses related to TPACK, and its components has increased significantly. Therefore, this change is expected to enhance pre-service mathematics teachers' TPACK levels and thereby increase the quality of mathematics education. It is well-known that these two types of anxiety experienced by teachers may cause students to experience mathematics anxiety and affect their mathematics learning capabilities (Baloglu, 2001; Hadley & Dorward, 2011).

Recommendations

This study revealed that pre-service mathematics teachers' mathematics anxiety was at a low level; however, considering the mediating effect of mathematics anxiety, it is recommended that necessary precautions be employed during the undergraduate education period to keep pre-service mathematics teachers' mathematics anxiety at a low. The first of these precautions is using technology in teaching content knowledge courses. Using communication and information technologies such as computer algebra systems, dynamic mathematics, and geometry software in field courses such as analysis, linear algebra, or geometry may enhance pre-service teachers' content knowledge and decrease their mathematics anxiety. Furthermore, this may also increase pre-service teachers' competencies to integrate technology in teaching mathematics. It is expected that pre-service mathematics teachers who can use technology more efficiently in their lessons will experience lesser mathematics teaching anxiety. Additionally, we can recommend more room for technology-based micro-teaching practices during pre-service teachers' undergraduate education to enhance their TPACK competencies.

Similarly, it is essential to guide pre-service teachers in integrating technology into their lessons during their teaching practicum. Hence, they may experience lesser

mathematics teaching anxiety when they become teachers. Similarly, mathematics teachers should be provided in-service training to improve their TPACK competencies and reduce their mathematics and mathematics teaching anxiety. Although both teachers and pre-service teachers are not expected to experience mathematics anxiety, this variable should be definitely included in the studies that examine the relationships among variables affecting mathematics teachers' competencies, given the mediating role of mathematics anxiety revealed in the current study. Besides, future studies should identify pre-service teachers' mathematics anxiety types before and after providing technology-supported training; hence, they can reveal the effect of technology-focused training on anxiety types. Additionally, we recommend that experimental studies separate pre-service teachers into groups of those experiencing mathematics and mathematics teaching anxiety, those experiencing mathematics teaching anxiety but not mathematics anxiety, those experiencing mathematics anxiety but not mathematics teaching anxiety, and those not experiencing both anxiety types.

This study has several limitations that should be considered while interpreting the results. First, pre-service teachers' perceptions regarding their TPACK competencies, mathematics anxiety, and mathematics teaching anxiety were measured through scales in this study. Therefore, the study data were collected based on the pre-service teachers' self-assessments and perceptions. Second, the obtained data can only account for the variables in the instruments. Herewith, future research may include other variables such as achievement and self-efficacy. Third, we think that measuring pre-service mathematics teachers' levels of knowledge regarding the TPACK framework directly would reveal more evident results; however, it is a challenging task requiring experimental studies. Therefore, researchers are advised to conduct mixed-method studies using methods such as observation and interviews. By this means, they can obtain more thorough results regarding pre-service teachers' TPACK competencies and anxiety levels.

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