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Adaptation of the Maker-Based Technological Pedagogical Content Knowledge Scale (Maker-TPACK) to Turkish for Pre-service Science Teachers

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Abstract

The aim of the study is to adapt the "Maker-Based Technological Pedagogical Content Knowledge" scale developed by Ku et al. (2021) for pre-service science teachers into Turkish. The study group for the research consists of 188 pre-service science teachers studying at the Department of Science Education at three state universities in Istanbul. This study was carried out using an exploratory sequential design, one of the mixed method typologies. As a result of confirmatory factor analyses, it was seen that the scale, which was adapted into Turkish, consisted of 7 sub-dimensions and 27 items, as in the original. These 7 sub-dimensions consist of Content Knowledge, Pedagogical Knowledge, Technological Knowledge, Pedagogical Content Knowledge, Technological Content Knowledge, Technological Pedagogical Knowledge, and Technological Pedagogical Content Knowledge. The Cronbach Alpha Reliability Coefficient of the scale is .948. The validity of the scale was confirmed via confirmatory factor analysis. As a result of confirmatory factor analyses, it was seen that the scale, which was adapted into Turkish, consisted of 7 sub-dimensions and 27 items, as in the original (X^2 =718.83, df=303, p= 0.00), and the x^2/df value for model fit was found to be 2.37, RMSEA: .080, RMR: .0498, SRMR: .0759, IFI: .966, NFI: .942, NNFI: .960 and CFI: .965. Because all fit values are in acceptable levels, the scale is usable and valid. The results of the study show that the adapted scale is a valid and reliable scale that can be used to measure the Maker-Based Technological Pedagogical Content Knowledge of pre-service science teachers.

Keywords: technological pedagogical content knowledge, maker movement, digital production tools, pre-service teachers, scale adaptation

Introduction

Today, which is described as the digital age, it has become compulsory for teachers to integrate technology into educational environments (Wu, 2013). In this respect, with the increase in value given to the use of technology in teacher education, it is expected that teachers' pedagogical and content knowledge competencies, as well as their ability to use technological knowledge together with these competencies—in other words, their Technological Pedagogical Content Knowledge (TPACK)—will have been developed (Koehler et al., 2007). This is because TPACK (Mishra & Koehler, 2008), which is expressed as the most important factor affecting technology integration in education, enables teachers to make their lessons more understandable and to help their students use technology efficiently (Jen et al., 2016).

The idea that teachers should integrate technology into teaching is not new. Mishra and Koehler (2006), who improved the work done by Shulman (1986), developed the TPACK model by adding the technology element to the concept of Pedagogical Content Knowledge. Later, Harris et al. (2009) updated the model by adding "context information" to the first TPACK model (Figure 1).

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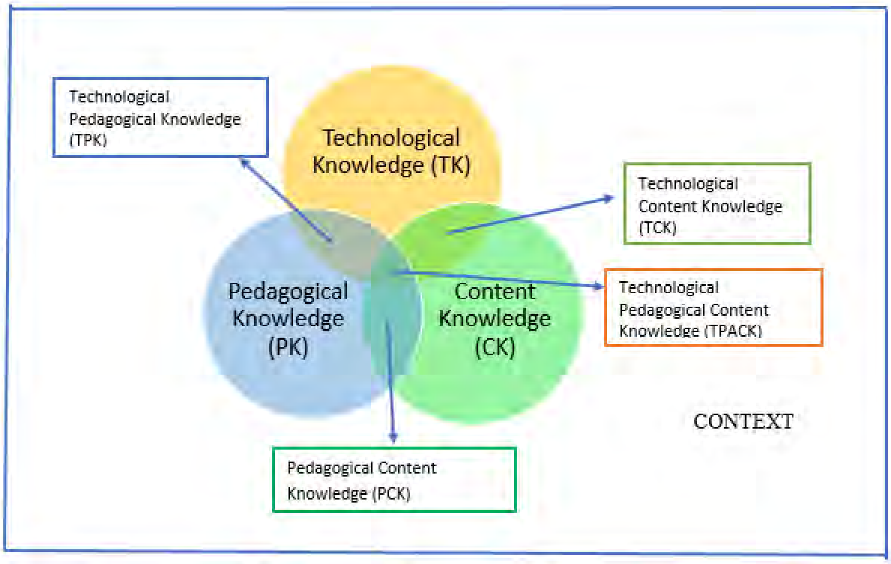

Figure 1. TPACK and types of information (Koehler & Mishra, 2009)

According to this model, there are three interconnected types of knowledge: Technological Knowledge, Pedagogical Knowledge, and Content Knowledge, and all these types of knowledge are affected by contextual knowledge (Harris et al., 2009). In the model, Content Knowledge (CK) refers to basic knowledge about the subject to be learned or taught in different disciplines such as science, history, art, or astrophysics; Pedagogical Knowledge (PK) refers to knowledge about methods and practices in the teaching and learning process; and Pedagogical Content Knowledge (PCK) expresses the knowledge with which teaching strategies will be taught. Technological Knowledge (TK) refers to the knowledge of using new and old technologies such as books, chalk, blackboards, internet and digital video; Technological Content Knowledge (TCK) refers to the knowledge of choosing the most appropriate technology to be used in teaching the subject; Technological Pedagogical Knowledge (TPK) refers to the knowledge of understanding how teaching and learning change when certain technologies are used; and, Technological Pedagogical Content Knowledge (TPACK), which is defined as a type of knowledge that is different from and be-yond the combination of Technological, Pedagogical and Content Knowledge, is explained as the knowledge of choosing appropriate technology and pedagogical techniques according to the learning needs of students. Contextual Knowledge, on the other hand, means that technological, pedagogical, and content knowledge are embodied in specific learning and teaching contexts (Harris et al., 2009; Koehler et al., 2013; Koehler & Mishra, 2009; Mishra & Koehler, 2008; Öztürk et al., 2020; Yanpar Yelken et al., 2013).

In the last ten years, many TPACK measurement tools have been integrated into educational environments, and the TPACK performances of pre-service teachers have been evaluated (Baran & Canbazolu Bilici, 2015; Kaleli & Yılmaz, 2015; Ku et al., 2021). By using TPACK measurement tools, besides pedagogical content knowledge, the performances in the application of technologies such as information and communication technologies (Kadıoğlu-Akbulut, Çetin-Dindar et al., 2020), interactive whiteboards (Bilici & Güler, 2016; Jang & Tsai, 2012), augmented reality (Jwaifell, 2019), and robotics (Yanış & Yürük, 2021) to teaching have been investigated. In our study, unlike others, the use of digital production tools is defined as technological knowledge. Digital production tools first came to the fore in 2008 when Stanford University launched the "FabLab@School" project (Blikstein, 2013). The tools mentioned here are the technologies enabling design and production, such as 3D printers, laser cutting and CNC machines, Arduino, Lego sets, and applications (Anderson, 2012; Blikstein, 2013; Ku et al., 2021; Lang, 2017; Schon et al., 2014).

Digital production tools are one of the technologies that are rapidly being integrated into educational environments as the maker movement develops and its potential is understood (Berry et al., 2010; Chan & Blikstein, 2018; Leinonen et al., 2020). The Maker Movement, on the other hand, is a movement that combines the Do It Yourself [DIY] culture and technology, based on the philosophy of learning by doing, where students create concrete or digital products to build knowledge, and where problem solving and content are associated with the real world (Schon et al., 2014). Maker refers to a person who tends to create products with technology and materials by tinkering with the world around her (Lang, 2017). It is stated in the literature that the Maker movement is closely related to project-based, design-based, and problem-based learning approaches (Chan & Blikstein, 2018; Moro et al., 2020; Smith et al., 2015). In addition, having systematically examined the studies on the maker movement and education in recent years, Schad and Jones (2019) have found that Maker-Based learning is considered together with STEM in more than half of the student-centered studies at the K–12 level. This is because the digital production tools used in Maker-Based learning are typically directly related to the learning and practice of STEM disciplines (Blikstein, 2013).

In order to reveal the educational potential of Maker, it is necessary to understand the ideas and new perspectives that it brings to the education system. In this regard, Edgar Tolson states that learning in the process does not occur with hands; hands only serve to shape, and the actual learning takes place with the mind (Lang, 2017). In Maker-Based learning, the goal is not just for students to produce end products. Maker-Based learning aims to give individuals the opportunity to use their new knowledge, which they have constructed in their minds by creating schemas, to create and test a product to solve a problem, and to use this product in the development process. In short, Maker-Based learning should focus on using and developing cognitive, affective, and psychomotor skills in a way that complements each other (Moro et al., 2020).

When viewed at the national level, an adaptation study of TPACK scale for primary school pre-service teachers (Kaya et al., 2013), STEM-Pedagogical Content Knowledge scale (Akçay & Avcı, 2022), Educational Robotics TPACK Self-Efficacy scale (Yanış & Yürük, 2021), Information and Communication Technologies-TPACK scale (Kadıoğlu-Akbulut et al., 2020) and TPACK self-efficacy scale development study for pre-service science teachers (Canbazolu Bilici et al., 2013; Kiray, 2016), Adaptation of 21st century skills-oriented TPACK scale for pre-service teachers in different branches (Alpaslan et al., 2021), TPACK self-efficacy scale study for pre-service mathematics teachers (Çetin & Erdoğan, 2018), TPACK scale development study for pre-service and actual social studies teachers (Akman & Güven, 2015) and the study of developing the TPACK-Deep scale for pre-service Turkish language and literature teachers (Yurdakul et al., 2012) were carried out in our country.

In their study with 339 pre-service teachers, Alpaslan, Ulubey, and Ata (2021) aimed to adapt the TPACK scale focused on 21st-century skills into Turkish. There are nine factors on the scale: PK, CK, TK, PCK, TPK, TCK, TPACK, Management, and Innovative Behavior. Confirmatory factor analysis was performed for the construct validity of the scale and Rasch analysis for its validity and reliability. As a result of the study, it was determined that the adapted scale was valid and reliable. In addition, it was revealed that pre-service teachers believed that they had sufficient knowledge of content and pedagogical issues, but their knowledge of technology and integrating it with pedagogical and context knowledge was at a satisfactory level. Canbazoğlu et al. (2013) carried out a comprehensive scale development study to determine self-efficacy beliefs for TPACK. The study was conducted with 808 pre-service science teachers. As a result of the study, a valid and reliable scale consisting of 52 items of 10-point Likert type was developed under 8 factors: PK, CK, PCK, TK, TCK, TPK, TPACK, and CK.

When the literature is examined, no study has been found in which the TPACKs of pre-service science teachers are examined with a Maker-Based approach. Teachers with Maker-Based TPACK can create teaching environments for their students to embody, build, and share their work in a safe environment (Blikstein, 2013) and improve their technological literacy with their innovative design and problem-solving abilities (Ku et al., 2021). Therefore, it becomes necessary to examine the Maker-Based TPACK levels of pre-service science teachers at the national level before starting their professional lives. For this reason, this study aims to adapt the "Maker-Based Technological Pedagogical Content Knowledge" scale developed in 2021 by Ku et al. who define the role of technology knowledge in TPACK as digital production tools, into Turkish in a way to measure the TPACK level of pre-service science teachers. It is anticipated that this tool will be a valuable measurement tool in teacher education in the future. This is because with this measurement tool, it will be ensured that pre-service teachers can understand their abilities, realize their shortcomings, and evaluate their performances.

Method

This study was carried out using an exploratory sequential design, one of the mixed method typologies. In the exploratory sequential design, firstly, qualitative data are collected and analyzed. According to the results obtained, the data is tested with quantitative methods in the second part of the research (Creswell & Plano Clark, 2014). Exploratory sequential design is an approach in mixed methods research where the researcher begins by exploring qualitative data and subsequently uses these findings in the quantitative research dimension (Creswell, 2014). In the process of developing a measurement tool, it is necessary to employ qualitative methods initially and then quantitative methods to create better-expressed and more comprehensive closed-ended questions for the development of scale items. The use of qualitative research is emphasized for generating hypotheses, and quantitative methods are required for testing these hypotheses (Bryman, 2006).

Participants

The study group for this research consists of 188 pre-service science teachers studying at three state universities in Istanbul. Participants were determined by using the purposive sampling method, one of the non-random sampling methods. 32 male (17%) and 156 female (83%) pre-service teachers participated in the study carried out in the 2021–2022 academic year. Participants consist of 12.8% 1st year (24 participants), 21.3% 2nd year (40 participants), 44.1% 3rd year (83 participants), and 21.8% 4th year (41 participants) university students, and they voluntarily participated in the study. The rule in the literature that it is necessary to work with a sample group that is five times the number of items in the scale whose validity and reliability will be determined was taken into consideration in the study (MacCallum et al., 1999).

Ethical Consent of the Research

Research permission for this scale adaptation study was obtained from the Istanbul University-Cerrahpaşa Social and Human Sciences Research Ethics Committee on April 14, 2021, with the number E-74555795. During this study, all the rules specified within the scope of the Higher Education Institutions Scientific Research and Publication Ethics Directive were complied with.

Procedure

In the process of adapting the Maker-Based Technological Pedagogical Content Knowledge (TPACK) Scale to Turkish, the following stages were followed in accordance with the research methodology: Identifying the need clarified by Seçer (2013); Determining the appropriate measurement tool; Building the translation team; performing forward and backward translations; Conducting language validity, creating the first version of the scale, and piloting it; Creating the first draft form, factor analysis, reliability and validity analyses, and finalization of the scale (Table 1).

Table 1. Scale adaptation stages

Stages of the Exploratory Sequential Pattern Method	Scale Adaptation Stages
Qualitative Data Collection and Analysis of Data	Identifying the need Determining the measuring tool Building the translation team Performing forward and backward translations
Development of the scale	Conducting language validation Creating the first version of the scale and piloting it Creating the First Draft Form
Quantitative Data Collection and Analysis of Data	Factor analysis Reliability and validity analyses Finalization of the scale
Reporting	Final version of the Maker-Based TPACK Scale

Identifying the Need

An existing Turkish measurement tool that could measure the Maker-Based TPACK knowledge of pre-service science teachers was searched in the relevant literature, but it was found out that there was no current and valid scale to meet the need.

Determining the Measuring Tool

In the scale development process, if an appropriate measurement tool is available in another culture, intercultural adaptation of that scale will be more convenient in terms of cost and time, and it will be effective for future cross-cultural comparison studies (Hambleton & Patsula, 1999; Şeker & Gençdoğan, 2014). In this context, it was decided to adapt the Maker-Based Technological Pedagogical Content Knowledge (TPACK) Scale developed by Ku et al. (2021) in order to eliminate this deficiency in the literature and to measure the Maker-Based technological pedagogical content knowledge level of pre-service science teachers. One of the researchers who developed the original scale, Dr. Kuen-Y Lin, was contacted via email, and permission was obtained for the adaptation of the scale.

The original form of the scale consists of 7 sub-dimensions and 27 items; these are: Content Knowledge (CK), Pedagogical Knowledge (PK), Technological Knowledge (TK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK) (Table 2). The internal reliability coefficient of the sub-dimensions of the original scale was between .72 and .86. The Cronbach Alpha value for the entire original scale was calculated as 0.95. The scale items are in 5-point Likert type: completely disagree (1), disagree (2), undecided (3), agree (4), and completely agree (5).

Table 2. Psychometric properties of the original scale

Sub-scales	**Number of items**	**Items**	**Cronbach Alpha**
Content Knowledge	3	1-2-3	.79
Pedagogical Knowledge	4	4-5-6-7	.81
Technological Knowledge	5	8-9-10-11-12	.79
Pedagogical Content Knowledge	4	13-14-15-16	.80
Technological Content Knowledge	4	17-18-19-20	.85
Technological Pedagogical Knowledge	3	21-22-23	.72
Technological Pedagogical Content Knowledge	4	24-25-26-27	.86
Total	**27**		**.95**

Building the Translation Team

In the selection of experts who would translate the scale, 8 expert translators consisting of researchers who have extensive knowledge of both languages, who have at least doctoral education in science education, and who have knowledge about the measured structure were determined. A Turkish language expert was also included in the translation team to determine the suitability of the Turkish language and grammatical structure in the creation of the Turkish form of the scale.

Performing Forward and Backward Translation

The items of the original scale were first translated into Turkish by four experts who are fluent in Turkish and English. Then, the scale items, which had been translated into Turkish, were translated back to the original language by four different field experts. The compatibility between the items in the forward and backward translation processes of the scale was examined, and linguistic and conceptual evaluations of the scale items were made by the relevant commission. In addition, in order to ensure the content validity of the scale, an evaluation was made by the commission regarding the extent to which the scale represents the subject it aims to measure and whether the quality intended to be measured is measured or not. In this study, the opinions of field experts were taken for content validity, and the opinions of linguistic experts were taken for face validity. For content validity, the suitability of the scale items for the pre-service teachers was examined by the expert group, and it was determined that the pre-service teachers were at a level that they could understand and answer the scale items. As a result of the examinations, necessary changes were made, and the final version of the scale was created for the Turkish form.

Conducting Language Validity

In order to determine the language validity of the scale, the original form and the Turkish form of the scale were applied to 31 pre-service teachers who were in the 3rd year (junior) of a state university, studying at the English Language Teaching Department. As a result of the analysis, the Pearson Correlation Coefficient (r) was determined to be .975, and it was determined that there was a high and significant relationship between the original form of the scale and the translated form. Likewise, the t value ($t(29) = -1.702, p = .088$) we found as a result of the paired samples t-test analysis for the language validity of the scale was smaller than the t value ($t(29) = 2.045$) in the table, which means that there is no significant difference between the original English version of the scale and the adapted Turkish version.

Creating the First Version of the Scale and Piloting It

As a result of the analyses made, the first form of the scale consisting of 27 items was created. The first draft form of the scale was applied to 15 science teacher candidates within the scope of the pilot study. At this stage, it is aimed at determining the readability, intelligibility, and average response time of the scale items, detecting expressions that are not understood or not clear by the pre-service teachers, and detecting spelling mistakes. After this stage, the scale was made ready for application and examination for factor analysis.

Findings

Construct Validity

In scale development and adaptation studies, Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) are performed to determine the construct validity of the scale. EFA helps to determine what kind of relationship there is between the items in a measurement tool and the sub-dimensions of the scale. CFA, on the other hand, is a statistical process performed to determine whether the model or structure previously revealed by EFA has been confirmed (Yaşlıoğlu, 2017). Since an existing model is tested in scale adaptation studies, researchers recommend direct Confirmatory Factor Analysis (CFA) be used (Hambleton & Patsula, 1999; Seçer, 2013; Gözüm & Aksayan, 2003). In this study, the LISREL 9.10 package program was used to evaluate the DFA results.

Before CFA, Kaiser-Meyer-Olkin (KMO) analyses were performed to determine the adequacy of the sample size and Barlett's Test of Sphericity analyses to determine whether the data were normally distributed. As a result of the analysis we conducted to determine the suitability of the data collected from the sample group to which the scale was applied for factor analysis, the Kaiser-Meyer-Olkin (KMO) value was found to be .915 and the Bartlett's test X^2 value was found to be 3980,395 ($p< .001$). The fact that the KMO value is greater than .90 in the study shows that the sample size is perfect for factor analysis. The significant result of Bartlett's test indicates that our data come from a multivariate normal distribution (Seçer, 2013).

Confirmatory Factor Analysis (CFA)

The compatibility of the Maker-Based Technological Pedagogical Content Knowledge (Maker-Based TPACK) Scale with Turkish culture was examined by the first-level CFA. As a result of the CFA carried out to determine the model fit of the Maker-Based TPACK Scale, it was seen that the scale, which was adapted into Turkish, consisted of 7 sub-dimensions and 27 items, as in the original. The chi-square fit value of the factor structure formed as a result of the analyses was found to be significant ($X^2 =718.83$, $df=303$, $p= 0.00$) and the x^2/df value for model fit was found to be 2.37 (Figure 2).

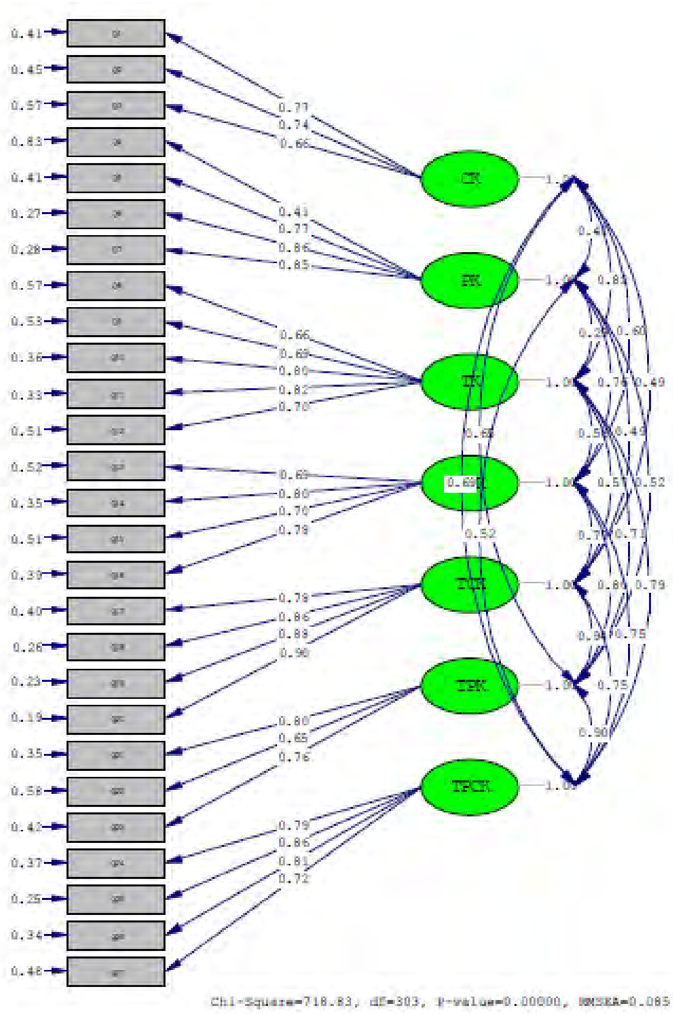

Figure 2. Standardized CFA analysis of item correlations in Maker-Based TPACK logic

When Figure 3 is examined, it is seen that the fit indexes of the Maker-Based TPACK Scale, which consists of 27 items and 7 sub-dimensions, are significant (X^2 =718.83, df=303, p= 0.00, X^2/df = 2.37). Since the fit indexes of the model were good, no modification was made between the items.

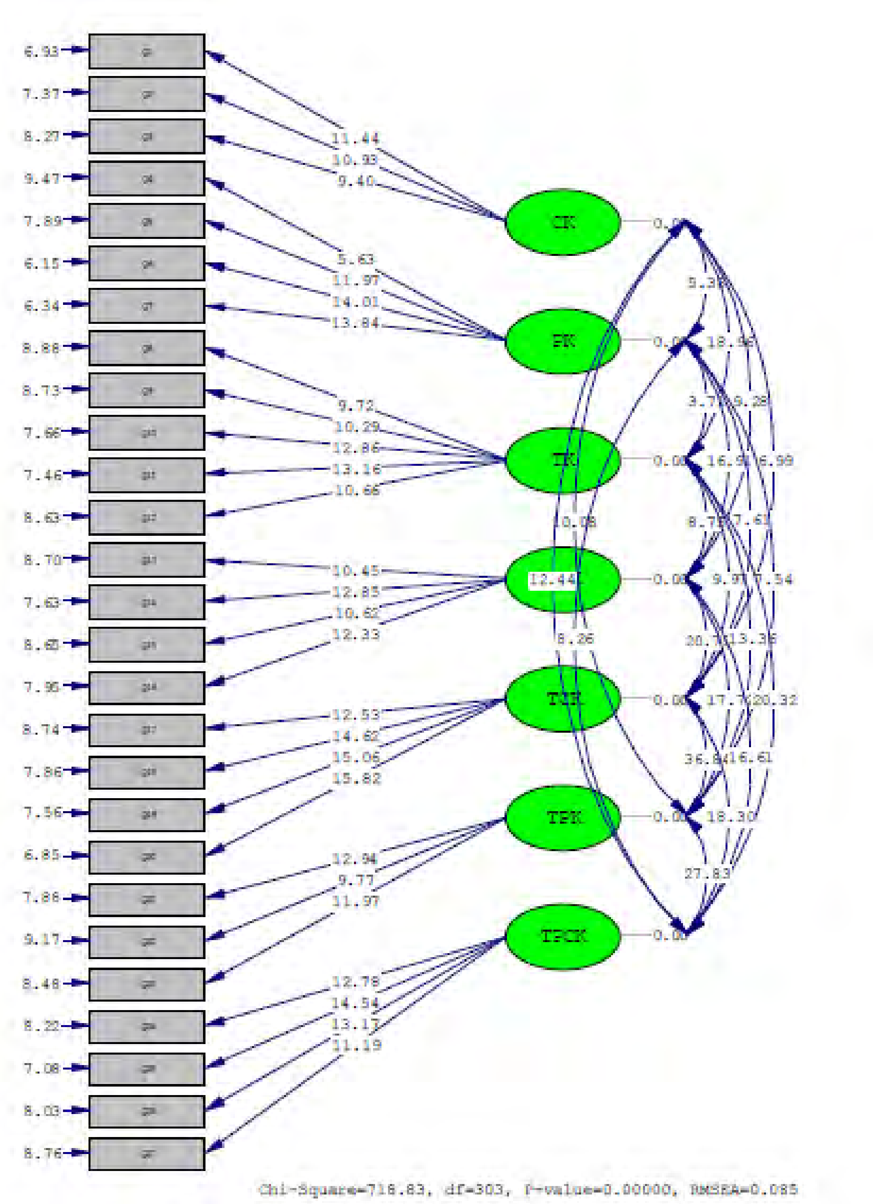

Figure 3. The t values of the item correlations of the Maker-Based TPACK scale

Model fit index values of the Maker-Based TPACK scale show that RMR (Root Mean Square Residual), CFI (Comparative Fit Index), NNFI (Non-Normed Fit Index), and IFI (Incremental Fit Index) values have a perfect fit level, while model fit indexes of Chi-Square Goodness (Chi-square fit test), RMSEA (Root Mean Square Error of Approximation), SRMR (Standardized Root Mean Square Residual), NFI (Normed Fit Index), and RFI (Relative Fit Index) values have acceptable fit levels. The obtained Chi-square fit index (2.37) shows that the sample from which the data was collected has a high agreement with the population (Yaşlıoğlu, 2017). The fit index values of the adapted Maker-Based TPACK Scale are presented in Table 3.

Table 3. Fit index values obtained as a result of the DFA of the Maker-Based TPACK Scale

Index	Perfect Fit Criteria*	Acceptable Compliance Criteria*	Research Finding	Result
x^2/df	0-2	2-3	2.37	Acceptable Fit
RMSEA	≤ .05	≤ .08	0.080	Acceptable Fit
RMR	≤ .05	≤ .08	0.0498	Perfect Fit
SRMR	≤ .05	≤ .08	0.0759	Acceptable Fit
CFI	≥ .95	≥ .90	0.965	Perfect Fit
NNFI	≥ .95	≥ .90	0.960	Perfect Fit
NFI	≥ .95	≥ .90	0.942	Acceptable Fit
IFI	≥ .95	≥ .90	0.966	Perfect Fit
RFI	≥ .95	≥ .90	0.933	Acceptable Fit

*Brown, 2006; Hu & Bentler, 1999; Kline, 2005; Seçer, 2013

Correlation Coefficients for Maker-Based TPACK Scale and Sub-Dimensions

Correlation coefficients were calculated in order to determine the relationship between the Maker-Based TPACK scale and the seven factors that make up the scale. As seen in Table 4, the correlation coefficients of the factors and the whole scale range between .639 and .874, indicating that there is a strong positive correlation.

Table 4. Correlation values between Maker-Based TPACK Scale and sub-dimensions

	CK	PK	TK	PCK	TCK	TPK	TPACK
Maker-Based TPACK	.731**	.639**	.805**	.818**	.820**	.850**	.874**

**Correlation is significant at the 0.01 level.

Findings Related to Reliability Analysis

The reliability index of the Maker-Based TPACK Scale, which was obtained as a result of adaptation, was calculated as .948. It was determined that the reliability indexes of the sub-dimensions of the scale ranged from .763 to .911. When compared with the reliability indexes of the original scale, the adapted Maker-Based TPACK Scale seems to be compatible (Table 5).

Table 5. Reliability coefficients of the Maker-Based TPACK Scale

Sub-Dimensions	Reliability Coefficient of the Adapted Scale (α)	Reliability Coefficient of the Original Scale (α)
Content Knowledge	.763	.79
Pedagogical Knowledge	.792	.81
Technological Knowledge	.850	.79
Pedagogical Content Knowledge	.829	.80
Technological Content Knowledge	.911	.85
Technological Pedagogical Knowledge	.790	.72
Technological Pedagogical Content Knowledge	.867	.86

Total	**.948**	**.95**

In order to determine the item discrimination degree in the scale, namely the validity, according to the scores of the participants, the difference in scores between the top 27% group and the bottom 27% group was analyzed with the independent sample t-test (Table 6). According to the results of the analysis, there is a statistically significant difference [$t(103) = -21.740$; $p < .05$] between the survey total scores of the lower and upper groups. While the survey score average of the upper group is 78.2157, the average score of the lower group is 112.1481. It can be said that the survey could measure the difference between the students in the lower and upper groups (Seçer, 2013).

Table 6. t-test results for the top 27% group and bottom 27% group of the scale

Groups	**N**	**Average**	**SS**	**t**	**p**
The top 27% group	51	78.2157	8.47187	-21.740	.00
The bottom 27% group	54	112.1481	7.51453		

Discussion and Conclusion

Adapting a scale that has been brought to the international literature to another language and culture has many benefits, such as obtaining common findings that can be easily understood by every reader, increasing the potential for generalization of the findings, providing ease of communication, obtaining comparable findings, and ensuring cooperation for international joint research (Şahin, 1994). With this point of view, and due to the absence of any scale for measuring the Maker-Based TPACK before, the "Maker-Based Technological Pedagogical Content Knowledge" scale developed by Ku, Loh, Lin, and Williams in 2021 was aimed at adapting into Turkish in a way to measure the TPACK level of pre-service science teachers. In order to ensure the language validity of the scale, the relationship between the Turkish version and the original version of the scale was examined after the translation and language experts' controls. As a result of Pearson Product Moment Correlation Analysis, it is seen that the Pearson Correlation coefficient (r) is .975 and language validity is provided. CFA was applied to test the accuracy of the 7 dimensions in the original version of the Maker-Based TPACK Scale and the dimensions in the Turkish version. As a result of the CFA performed to determine the model fit of the Maker-Based TPACK Scale, it is seen that the scale, which is adapted into Turkish, consisted of 7 sub-dimensions and 27 items, as in the original. These 7 sub-dimensions consist of Content Knowledge, Pedagogical Knowledge, Technological Knowledge, Pedagogical Content Knowledge, Technological Content Knowledge, Technological Pedagogical Knowledge, and Technological Pedagogical Content Knowledge. The Cronbach Alpha Reliability Coefficients of these sub-dimensions are .763, .792, .850, .829, .911, .790 and .867, respectively. The Cronbach Alpha Reliability Coefficient of the scale is .948.

In scale development and adaptation studies, both Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) are employed to assess construct validity. EFA helps identify relationships between measurement tool items and scale sub-dimensions, while CFA confirms the previously identified model or structure (Yaşlıoğlu, 2017). For scale adaptation, direct use of CFA is recommended by researchers (Hambleton & Patsula, 1999; Seçer, 2013; Gözüm & Aksayan, 2003). This study used LISREL 9.10 for CFA evaluation. Prior to CFA, Kaiser-Meyer-Olkin and Bartlett's Test of Sphericity analyses ensured sample adequacy and data normality, respectively. Analysis results indicated a KMO value of .915 and a significant Bartlett's test ($X^2 = 3980.395$, $p < .001$), supporting the suitability of the data for factor analysis (Seçer, 2013).

As a result, the factors of the adapted version of the "Maker-Based Technological Pedagogical Content Knowledge" scale and the items under these factors have the same structure as the original scale. As a result of the analyses, the data collected within the scope of the study show that the adapted scale is a valid and reliable scale that can be used to measure the Maker-Based Technological Pedagogical Content Knowledge of pre-service science teachers. In Turkish literature, there is no measurement tool that evaluates the Maker-Based TPACKs of pre-service teachers. The Maker movement is becoming increasingly popular in Turkey as well as in the international arena. In particular, the establishment of the STEM & Maker Lab (http://www.hstem.hacettepe.edu.tr/en) at Hacettepe University, the establishment of a STEM laboratory (http://stemokulu.com/stem-lab/) at Istanbul Aydın University, and the start of maker trainings at the same university are strong indications of this fact. Considering that teachers, who play a key role in the dissemination of Maker education, should develop their Maker-Based TPACK levels and examine this development before starting their professional lives, it is expected that the adapted scale will make a great contribution to the field.

Recommendations

The scale presented in the study can be used to evaluate pre-service science teachers' maker-based TPACKs. It can also be used to determine to what extent various methods and techniques such as project-based learning, problem-based learning, and design-based learning affect maker-based TPACK. In future studies, in order to increase the generalizability of the adapted scale; validity and reliability analyses can be retested on the data to be obtained from pre-service teachers studying in different departments such as mathematics, social studies and preschool teaching.

Author (s) Contribution Rate
All authors contributed equally to the article.

Conflicts of Interest
There is no conflict of interest

Ethical Approval
Ethical permission (14/04/2021 with the number E-74555795) was obtained from Istanbul University-Cerrahpaşa Social and Human Sciences Research Ethics Committee for this research.

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APPENDIX

Appendix-1: Turkish Version of Maker-Based TPACK Scale

Kesinlikle Katılmıyorum	Katılmıyorum	Kararsızım	Katılıyorum	Kesinlikle Katılıyorum
1	2	3	4	5

No	Madde	Kesinlikle Katılmıyorum	Katılmıyorum	Kararsızım	Katılıyorum	Kesinlikle Katılıyorum
1	Yeterli teknolojik bilgiye sahibim					
2	Teknolojiyi konu uzmanlarının gözünden değerlendirebilirim.					
3	Teknolojiyle ilgili içeriği keşfetme ve anlama konusunda daha derinlere inebilirim.					
4	Öğrencilere derinlemesine düşünmeyi öğretmek için zorlu görevler geliştirebilirim.					
5	Öğrencilerime uygun çalışma stratejileri benimsemeleri talimatını verebilirim.					
6	Öğrencilerimin çalışmalarını yönetmelerine yardımcı olabilirim.					
7	Öğrencilerimin çalışma stratejileri üzerinde düşünmelerine yardımcı olabilirim.					
8	Dijital üretim araçlarını verimli bir şekilde kullanabilirim.					
9	Farklı dijital üretim araçlarını kullanmayı kolayca öğrenebilirim.					
10	Dijital üretim araçlarını kullanırken, ilgili teknik sorunları nasıl ele alacağımı biliyorum.					
11	Dijital üretim araçlarıyla ilgili en son bilgileri anlayabiliyorum.					
12	İlgili dijital üretim araçlarını çalıştıran yazılımı (bilgisayar çizim yazılımı dahil) kullanabilirim.					
13	Gruplar halinde öğrenciler için yapımcı etkinlikleri planlayabilirim.					

14	Öğrencilerime, grup oluşturucu etkinlikleri sırasında verimli tartışmalar yapmaları için talimat verebilirim.					
15	Dijital fabrikasyon araçlarını kullanmasam bile, öğrencilerin teknoloji eğitimi hakkındaki efsanelerine değinmeye yardımcı olabilirim.					
16	Dijital fabrikasyon araçlarını kullanmasam bile, öğrencilerin teknoloji hakkında İçerik Bilgisi edinmelerine yardımcı olmak için farklı yöntemler kullanabilirim.					
17	Öğrencilerime gerçek dünyadaki durumları tanıtmak için dijital üretim araçlarını kullanabilirim.					
18	Öğrencilerimin tasarım düşüncelerini ifade etmek için dijital üretim araçlarını kullanmalarını sağlayabilirim.					
19	Öğrencilerimin tasarım düşüncelerini test etmek ve ayarlamak için dijital üretim araçlarını kullanmalarını sağlayabilirim.					
20	Öğrencilerimin bilgilerini farklı şekillerde sunmaları için dijital üretim araçlarını kullanmalarını sağlayabilirim.					
21	Öğrencilerimin diğer öğrencilerle işbirliği yapmak için dijital üretim araçlarını kullanmalarını sağlayabilirim.					
22	Teknolojiyle ilgili üretici tabanlı öğretim etkinliklerini tasarlarken hangi dijital üretim araçlarının kullanılacağını biliyorum.					
23	Teknolojiyle ilgili çalışma içeriğini sunmak için uygun dijital üretim araçlarını kullanabilirim.					
24	Teknolojik içeriği öğretme sürecine teknolojiyi, dijital üretim araçlarını ve öğretim yöntemlerini uygun şekilde entegre edebilirim.					
25	Teknolojik öğretim içeriğimi ve yöntemlerimi ve ayrıca öğrencilerin çalıştığı içeriği geliştirmek için uygun dijital üretim araçlarını seçebilirim.					
26	Öğretim sırasındaki gözlemlerime dayanarak teknolojiyi, dijital üretim araçlarını ve öğretim yöntemlerini uygun şekilde entegre etmek için farklı öğretim stratejileri uygulayabilirim.					
27	Okulumdaki diğer öğretmenlere teknolojiyi, dijital üretim araçlarını ve öğretim yöntemlerini entegre etme konusunda yardımcı olabilirim					