JPII 11(1) (2022) 142-154

Jurnal Pendidikan IPA Indonesia

http://journal.unnes.ac.id/index.php/jpii

EXAMINING PERCEPTIONS OF TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK): A PERSPECTIVE FROM INDONESIAN PRE-SERVICE TEACHERS

I. Irwanto*[1], I. W. Redhana[2], B. Wahono[3]

[1]Department of Chemistry Education, Universitas Negeri Jakarta, Indonesia
[2]Department of Science Education, Universitas Pendidikan Ganesha, Indonesia
[3]Department of Biology Education, Universitas Jember, Indonesia

DOI: 10.15294/jpii.v11i1.32366

Accepted: October 2nd 2021. Approved: March 30th 2022. Published: March 31st 2022

ABSTRACT

Understanding pre-service teachers' perceived technological pedagogical content knowledge (TPACK) is important to better prepare them for their future STEM-related careers. Thus, this study aims to examine pre-service teachers' perceptions of TPACK in relation to their age, gender, and grade level. To achieve this goal, a cross-sectional survey design was used in this quantitative non-experimental research. Participants included 481 (136 male; 345 female) pre-service teachers from four public and private universities in Indonesia. A 27-item PT-TPACK Survey was used to gather data. Independent *t*-test, ANOVA, and Person's correlation were executed to analyze the data. The findings suggested that pre-service teachers performed the highest self-confidence level in pedagogy knowledge and the lowest in technology knowledge. They rated themselves above four on a five-point scale. No significant differences for all TPACK dimensions were found in terms of gender and age. In addition, there was a significant difference between pre-service teachers who were at the postgraduate level and those at the undergraduate level. Moreover, a high positive and significant correlation existed between all six TPACK domains. It is suggested that pre-service teacher preparation programs should facilitate pre-service STEM teachers how to integrate pedagogy, content, and technology together to create effective technology-enhanced learning in their subjects.

Keywords: age; gender; grade level; perceptions; pre-service teachers; TPACK

INTRODUCTION

In the twenty-first century, the rapid development of ICT has provided a massive acceleration to all aspects of education. However, to successfully utilize digital technology tools in an educational context, pre-service teachers should be able to integrate their technological knowledge and apply it in a particular educational context (Irmak & Tüzün, 2018). Thus, it seems important to effectively nurture pre-service teachers' technological pedagogical and content knowledge (TPACK) in teacher training programs (Irwanto, 2021; Kartimi et al., 2021). It aims to enable pre-service teachers to effectively integrate technology into their future careers. It should be noted that enhancing TPACK is important for pre-service teachers to not only focus on how to use technological skills but also apply digital technologies in their instruction. In previous studies, the benefits of integrating TPACK in teaching practices have been well-documented, such as the use of technology can enhance pre-service teachers' confidence (Adamy & Boulmetis, 2006; Özçakır & Aydın, 2019), promote motivation rates (Gómez-García et al., 2021), and help better visualization of abstract concepts (Irmak & Tüzün, 2018). Due to the popularity of techno-

***Correspondence Address**
E-mail: irwanto@unj.ac.id

logy in education, TPACK is increasingly becoming an essential framework adopted by many researchers and educators to enhance pre-service teachers' knowledge of integrating digital technologies into their classroom teaching and learning.

By adding a dimension related to technological knowledge (TK), TPACK—proposed by Mishra & Koehler (2006)—is actually rooted in Shulman's (1986) model, which is based on two main dimensions related to content knowledge (CK) and pedagogical knowledge (PK). As a result, all three dimensions of knowledge intersect into seven factors, such as TK, PK, CK, technological pedagogical knowledge (TPK), pedagogical content knowledge (PCK), technological content knowledge (TCK), and TPACK. This reflects that in the TPACK model, technological skills, subject matter knowledge, and pedagogical competencies of pre-service teachers should be developed together rather than being improved separately. Hence, to be more effective in classrooms, pre-service teachers are expected to employ technology integrated with pedagogy and content. In the literature, the TPACK framework has been used frequently in the last decade. Nevertheless, earlies studies suggest the need for studies analyzing the relationship between TPACK and demographic factors, such as gender, age, and grade levels (Chai et al., 2016). To date, the individual personal factors affecting pre-service teachers' TPACK levels remain unclear. Hence, it seems that there is a vital need to investigate how demographic factors affect pre-service teachers' perceived TPACK.

Nowadays, many researchers have indicated an interest in the differences in the TPACK of pre-service teachers with respect to gender and revealed various findings. For instance, Muhaimin et al. (2019) explored 356 Indonesian science teachers' perceptions of TPACK and found that there is a significant gap between male and female teachers in terms of TK, PK, TPK, and TPACK. Similarly, Çetin-Berber and Erdem (2015) investigated 491 Turkish pre-service teachers' perceived TPACK and reported a significant gap in pre-service teachers' perceptions of the TPACK with regard to gender. In a study, Jamieson-Proctor et al. (2010) analyzed the confidence levels of TK and TPACK among final year education students in two Queensland universities and they also found a significant gap between female and male pre-service teachers with regard to their confidence to use ICT for teaching and learning purposes. A similar trend was also found in the study of Luik et al. (2017) who believed that the TPACK of pre-service teachers was influenced by gender in favor of male students. However, other studies showed no significant difference in terms of TPACK scores and gender. For example, Yildiz (2017) investigated the techno-pedagogical competencies of 552 pre-service elementary mathematics teachers in relation to some variables and reported no statistically significant gap between the techno-pedagogical competencies of female and male pre-service teachers. Supportively, Lin et al. (2013) explored 222 Singaporean in-service and pre-service science teachers' perceptions of TPACK. They concluded that gender had no significant effect on pre-service teachers' perceptions of technological knowledge and pedagogical knowledge. This insignificant result is also supported by previous research (e.g., Koh & Sing, 2011; Altun & Akyıldız, 2017). The lack of agreement among researchers indicates that more studies are needed. In light of the above-mentioned studies, it is necessary to understand the effect of gender on pre-service teachers' perceived TPACK. Therefore, in the current study, the influence of gender on the pre-service teachers' TPACK was explored further.

In published studies, it was reported that age was a dominant variable in relation to TPACK competencies. In their study, Luik et al. (2017) investigated the perceptions of TPACK among 413 pre-service teachers in Estonia and found differences in perceived TPACK according to age. In another study, TK was significantly and positively associated with pre-service teachers' age (Lin et al., 2013). Muhaimin et al. (2019) also found that there was a significant gap between TK and TPK in terms of age. Different from previous studies, some scholars and researchers could not find any age differences in any perceived TPACK components. For instance, Cetin-Berber and Erdem (2015) documented that there was no significant gap in pre-service teachers' perceptions of TPACK with regard to age. In the Indonesian context, Muhaimin et al. (2019) agreed that there was no significant difference in PK, CK, PCK, TCK in terms of age. Empirical studies have claimed that age may not be a significant factor influencing pre-service teachers' perceptions of TPACK (Koh et al., 2010; Koh & Sing, 2011). This contradictory result is also supported by Jamieson-Proctor et al. (2010) who reported that there was no significant gap in TPACK confidence by age of pre-service teachers. Previous studies have documented the inconsistency of the effect of age on perceptions of TPACK. It is seen that there is a contradiction for age groups variable in previous literature. Thus, it is necessary to explore how pre-service teachers' age affects the dimensions of TPACK in the current study.

In addition to gender and age, grade level plays a vital role in pre-service teachers' perceived TPACK. In prior studies, a significant gap in pre-service teachers' perceptions of TPACK was found across grade levels. For example, Keser et al. (2015) examined the TPACK competencies of 712 pre-service teachers based on various variables. At the end of the study, they reported that there was a statistically significant difference gap between first-year and fourth-year students in relation to their TPACK competencies. In a recent survey, Koyuncuoğlu (2021) examined the TPACK perceptions of 186 graduate students based on some variables in Turkey and found a significant difference among the mean scores of PK, CK, and TCK by education level. He also reported that the mean PK, CK, and TCK scores of the doctoral students were significantly greater than those of the master's students. Similar to earlier studies, Çetin-Berber and Erdem (2015) noted that grade level had an effect on pre-service teachers' TPACK regarding their perceptions of PCK and TCK. They asserted that fourth-year students rated PCK significantly higher than second-year students, and third-year students perceived TCK significantly greater than second-year students.

Moreover, Luik et al. (2017) emphasized that the TPACK perceptions of postgraduate students were significantly greater compared with the perceptions of undergraduate students. In other words, this finding can be interpreted that the grade level may have an impact on the competency level of the TPACK. Unfortunately, the findings mentioned above are in contrast to previous studies. For instance, Altun (2019) examined the TPACK competencies of 481 pre-service early childhood teachers and reported no statistically significant differences among the pre-service teachers' TPACK scores in relation to their grade level. Similarly, Koyuncuoğlu (2021) declared that there was no significant difference in the mean TK, PCK, TPK, and TPACK scores based on the graduate education program. Through a cross-sectional design, Turgut (2017) investigated 174 Turkish pre-service teachers' self-perceived TPACK and she also reported that there was no significant gap between fourth-year and second-year students related to TK, TCK, TPK, and TPACK. Further, an insignificant difference was also found between second-year and third-year students with regard to CK, PK, and PCK. It is seen that there has been no agreement in the literature on the effect of grade level on pre-service teachers' TPACK. Therefore, pre-service teachers' perceptions of TPACK were investigated in terms of grade level to analyze whether there were significant differences. In general, the finding of previous studies suggest that gender, age, and grade level might correlate to TPACK; thus, the influence of sociodemographic factors should be examined further.

In the literature, for instance, Çetin-Berber and Erdem (2015) expressed that PK and CK contributed significantly to pre-service teachers' TPACK domains. In the study of Lin et al. (2013), it was also found that science teachers' perceived knowledge of technology, pedagogy, and content (TPC) significantly and positively correlated with all the TPACK factors. A study in the UEA by Khine et al. (2016) explored the relationships among the six TPACK factors. They found that TK, PK, CK, and TPK were significant determinants of pre-service teachers' TPK, PCK, and TPACK. This is in accordance with the study of in-service teachers which found that a strong positive and significant relationship appeared between TCK and TPK, TPK and TPACK, and TCK and TPACK (Roig-Vila et al., 2015). Whereas in some other studies, each of the TPACK components (e.g., TK) was not a significant determinant of pre-service teachers' TPACK development (Çetin-Berber & Erdem, 2015). Another study reported that CK was not significantly associated with PCK and also there was no significant relationship between PCK and TPACK (Khine et al., 2016). Moreover, in Germany, Krauskopf and Forssell (2018) investigated the relationship between TPACK and several variables and they also found that there was no significant correlation between TK, PK, and TPACK among pre-service teachers. This indicates that the relationship between the TPACK factors remains unclear. Based on the existing literature, the researchers argued that there is a need to examine the correlation between TPACK dimensions in order to make this possible relationship clearer. Besides, it was assumed to be important to analyze the elements influencing TPACK (e.g., gender, age, grade level) among Indonesian pre-service teachers. Hence, the current study is expected to contribute to the TPACK literature and provide information for higher education institutions to design teacher development programs.

According to the aforementioned issues, the present study aimed to explore pre-service teachers' perceptions of TPACK with respect to their gender, age, and grade levels and to investigate whether there is a statistically significant relationship between TPACK factors. Depending on this purpose, the specific research questions addressed in this study are the following: (1) Is there a statistically significant difference between

pre-service teachers' TPACK perceptions by gender?; (2) Is there a statistically significant difference between pre-service teachers' TPACK perceptions by age? ; (3) Is there a statistically significant difference between pre-service teachers' TPACK perceptions by grade level?; (4) Is there a statistically significant relationship between pre-service teachers' TPACK domains?

METHODS

The study used a cross-sectional survey method. In this quantitative research design, the survey method helps researchers describe an event or phenomenon in the form of its existence without any intervention that affects the results (Fraenkel et al., 2019). To meet the purpose of the study, the TPACK scores of pre-service STEM teachers were investigated by considering their gender, age, and grade levels at one point in time.

The sample in this study was 481 pre-service teachers at 4 public and private universities in Indonesia who were recruited using a purposive sampling technique. The researchers gathered data at the end of the even semester in the 2020-2021 academic year. Out of the total, most of the participants were females (n = 345; 71.7%), within 23-25 age range (n = 230; 47.8%), and third-year Bachelor of Education (BEd) students (undergraduate level: n = 283; 58.8%) who had completed a microteaching course. In this survey, participants were recruited from Science, Technology, Engineering, and Mathematics (STEM)-related majors, for example, Department of Chemistry Education, Department of Physics Education, Department of Biology Education, Department of Mathematics Education, Department of Educational Technology, Department of Electronic Engineering Education, Department of Culinary Education, and Department of Informatics and Computer Engineering Education. All pre-service teachers were invited to complete online surveys using Google Forms. In the context of the current COVID-19 pandemic, online surveys can be quickly created and distributed with a wide reach (Evans & Mathur, 2005). More specifically, the demographic information of the respondents is exhibited in Table 1.

Table 1. Demographic Profile of Respondents

Variable	Frequency (n)	Percentage (%)
Gender		
Male	136	28.3
Female	345	71.7
Age		
Between 20 - 22 Years	204	42.4
Between 23 - 25 Years	230	47.8
Exceeded 25 years	47	9.8
Grade Level		
2nd Year BEd	105	21.8
3rd Year BEd	283	58.8
4th Year BEd	33	6.9
Master of Education (MEd)	60	12.5
Total	481	100.0

To explore the TPACK of pre-service teachers, the researchers adapted the Pre-service Teacher Technological Pedagogical Content Knowledge (PT-TPACK) Survey originally developed by Lux et al. (2011). The original scale consisted of two parts. Specifically, the first part included questions aimed at gathering demographic data on the respondents. The second part covered 27 items in 6 TPACK domains; Technology Knowledge (TK; 4 items), Pedagogy Knowledge (PK; 4 items), Content Knowledge (CK; 3 items), Pedagogical Content Knowledge (PCK; 3 items), Technological Pedagogical Knowledge (TPK; 5 items), and Technological Pedagogical Content Knowledge (TPCK; 8 items). The PT-TPACK Survey has a 5-point Likert scale format (from strongly disagree '1' to strongly agree '5'). The lowest score obtained from the scale was 27 while the highest was 135. For the adaptation of the study, the instrument was then translated into Indonesian using a standard protocol. Three experts holding a Ph.D. in Science Education were

asked to validate the scale. After being piloted with 367 pre-service teachers, all TPACK domains had an alpha coefficient between 0.63 and 0.93. This shows that the PT-TPACK survey has high reliability to evaluate the confidence level of pre-service teachers towards TPACK. Thus, the researchers decided to utilize this instrument to collect data in the main study. The coefficients of Cronbach's alpha obtained in both the original study and the current study are presented in Table 2. As a note, each respondent completed the survey in about 15-20 minutes.

Table 2. Reliability of TPACK Scale

Domains	Items	The α Value in the Original Study (n = 120)	The α Value in the Present Study (n = 367)
TK	4	0.75	0.63
CK	3	0.77	0.80
PK	4	0.77	0.91
PCK	3	0.65	0.81
TPK	5	0.84	0.90
TPCK	8	0.90	0.93

Written permission was obtained prior to collecting data. An Indonesian version of the PT-TPACK survey was performed as the main data collection tool. At the beginning of the survey, respondents were informed about the purpose of the investigation, the content of the survey, and the instructions for completing them. Keep in mind that their identities were kept anonymous. Due to on a voluntary basis, their participation would not affect their final exam scores. All pre-service teachers were allowed to complete the PT-TPACK survey at a place of their own choosing at a time convenient for them through a self-administered survey (Robson & McCartan, 2015). Finally, respondents were required to provide some of their demographic information in terms of gender, age, and grade level without mentioning their names. After the online survey was administered to all participants, data were downloaded, coded in MS Excel 2019, and then transferred to IBM SPSS software for statistical analysis. A high score in the survey indicated a high perception of TPACK.

The data obtained in the current study were analyzed using descriptive statistics such as mean scores, standard deviations, frequencies, and percentages. First, normality and homogeneity of the data were checked using the Kolmogorov-Smirnov and Levene tests. After meeting the assumptions of normality and homogeneity (Pallant, 2020), parametric statistics were employed. Then, an independent sample *t*-test was adopted to explain the difference in TPACK scores between male and female pre-service teachers regarding TK, CK, PK, PCK, TPK, and TPCK. The pre-service teachers' ages and their grade levels were separately categorized into three (i.e., 20-22, 23-25, and over 25) and four levels (i.e., 2nd year, 3rd year, 4th year BEd, and MEd), respectively. Furthermore, one-way analysis of variance (ANOVA) and Tukey's HSD Post Hoc test were calculated to examine any differences among these groups. Finally, to explain whether there was a statistically significant positive correlation between all TPACK perception domains, Pearson's correlation was employed. The strength of the relationship was adapted from Cohen's (1988) criteria; 0.10 to 0.29 for a weak relationship, 0.30 to 0.49 for a moderate relationship, and higher than 0.50 for a strong relationship between variables. The researchers used IBM SPSS 25 software for the statistical analyses. In order to analyze the data, the significance level was set at 0.05.

RESULTS AND DISCUSSION

In this section, according to the research objectives, the results of the analysis of all TPACK components regarding descriptive statistics, *t*-test, one-way ANOVA, and Pearson's correlation are presented as follows.

Descriptive statistics (i.e., minimum and maximum scores, mean scores, and standard deviations) for pre-service teachers' perceptions about their technological pedagogical and content knowledge are shown in Table 3.

Table 3. Descriptive Analysis of the TPACK Survey

Domains	Min	Max	Mean	SD
Technology Knowledge (TK)	1.250	5.000	4.159	0.535
Content Knowledge (CK)	2.670	5.000	4.266	0.514
Pedagogy Knowledge (PK)	1.000	5.000	4.473	0.518
Pedagogical Content Knowledge (PCK)	2.330	5.000	4.299	0.508
Technological Pedagogical Knowledge (TPK)	1.000	5.000	4.277	0.529
Technological Pedagogical Content Knowledge (TPCK)	1.380	5.000	4.203	0.526
All TPACK Domains	2.110	5.000	4.282	0.437

According to the results expressed in Table 3, most pre-service teachers performed high levels of PK (M = 4.473; SD = 0.518) and PCK (M = 4.299; SD = 0.508). Furthermore, respondents rated the highest on TPK (M = 4.277; SD = 0.529) followed by CK (M = 4.266; SD = 0.514), TPCK (M = 4.203; SD = 0.526), and TK (M = 4.159; SD = 0.535). Overall, it can be inferred that pre-service teachers' perceptions of the six dimensions on the TPACK scale appear to be greater than the average score of the Likert scale, which is 4.282 out of 5.0. In sum, pre-service teachers generally perceived their TPACK at a fairly high level. Higher mean scores refer to higher perceptions about TPACK for pre-service teachers.

In line with the first research question, an independent sample t-test was used to identify whether all TPACK domains (i.e., TK, CK, PK, PCK, TPK, TPCK) differed by gender. Table 4 presents the results of the analysis.

Table 4. TPACK Perceptions of Pre-service STEM Teachers With Respect to Gender

Domains	Gender	*N*	Mean	SD	*t*	*df*	*p*
TK	Male	136	4.101	0.554	-1.491	479	0.137
	Female	345	4.182	0.527			
CK	Male	136	4.209	0.579	-1.545	479	0.123
	Female	345	4.289	0.484			
PK	Male	136	4.364	0.505	-2.932	479	0.004
	Female	345	4.517	0.518			
PCK	Male	136	4.255	0.539	-1.202	479	0.230
	Female	345	4.317	0.496			
TPK	Male	136	4.244	0.571	-0.865	479	0.388
	Female	345	4.290	0.512			
TPCK	Male	136	4.179	0.578	-0.638	479	0.524
	Female	345	4.213	0.505			
All Domains	Male	136	4.226	0.472	-1.774	479	0.077
	Female	345	4.305	0.421			

As visualized in Table 4, female pre-service teachers scored slightly higher than males in all domains of the TPACK framework; TK, PK, CK, PCK, TPK, and TPCK, although not statistically significant. Based on the results of the test, there was only a gap between male and female pre-service teachers concerning the PK scores (t = -2.932; p = 0.004). Overall, the self-efficacy of male pre-service teachers was slightly lower than females with respect to all TPACK dimensions. In this regard, none of the other domains (i.e., TK, CK, PCK, TPK, TPCK) revealed significant differences in terms of gender. Furthermore, the largest and smallest differences in mean scores by gender were found in PK (i.e., 0.153) and TPCK (i.e., 0.034), respectively.

In response to the second research question, one-way ANOVA was executed to explain whether perceived TPACK components differ regarding their ages. The results are exhibited in Table 5.

Table 5. Pre-service STEM Teachers' TPACK Difference by Age

Domains	Age	*N*	Mean	SD	*F*	*p*
TK	(1) Between 20 - 22 Years	204	4.147	0.572	0.247	0.781
	(2) Between 23 - 25 Years	230	4.176	0.515		
	(3) Exceeded 25 years	47	4.128	0.477		
CK	(1) Between 20 - 22 Years	204	4.267	0.520	3.000	0.051
	(2) Between 23 - 25 Years	230	4.232	0.495		
	(3) Exceeded 25 years	47	4.433	0.552		
PK	(1) Between 20 - 22 Years	204	4.463	0.571	0.617	0.540
	(2) Between 23 - 25 Years	230	4.466	0.486		
	(3) Exceeded 25 years	47	4.553	0.423		
PCK	(1) Between 20 - 22 Years	204	4.263	0.508	2.919	0.055
	(2) Between 23 - 25 Years	230	4.299	0.506		
	(3) Exceeded 25 years	47	4.461	0.500		
TPK	(1) Between 20 - 22 Years	204	4.271	0.570	0.969	0.380
	(2) Between 23 - 25 Years	230	4.263	0.484		
	(3) Exceeded 25 years	47	4.379	0.552		
TPCK	(1) Between 20 - 22 Years	204	4.238	0.532	1.774	0.171
	(2) Between 23 - 25 Years	230	4.158	0.516		
	(3) Exceeded 25 years	47	4.278	0.544		
All Domains	(1) Between 20 - 22 Years	204	4.276	0.461	1.616	0.200
	(2) Between 23 - 25 Years	230	4.266	0.418		
	(3) Exceeded 25 years	47	4.390	0.413		

When Table 5 is examined, there was a gradual increase of mean scores of PK and PCK domains from the youngest to the oldest age groups. In addition, pre-service teachers who were older than 25 years old had more positive perceptions of the CK domain compared to those in 23-25 age group ($F = 3.000$; $p = 0.051$). It was also observed that on the PCK domain, respondents who were older than 25 years old ($M = 4.461$; $SD = 0.500$) had greater scores than those who were in 20-22 age group ($M = 4.263$; $SD = 0.508$). Overall, the results of the study revealed that there was a gap between the pre-service teachers who were older than 25 years old ($M = 4.390$; $SD = 0.413$) and in 23-25 age group ($M = 4.266$; $SD = 0.418$) and those in 20-22 age group ($M = 4.276$; $SD = 0.461$) in terms of all TPACK dimensions. Nevertheless, it was seen that the ANOVA indicated no significant gap between the age groups in relation to all of these domains of TPACK. Since the results were not statistically significant, the Post-hoc test was not performed.

Aiming to determine whether all TPACK fields differ according to grade level variables, one-way ANOVA was employed to address the third research question. Table 6 summarizes the results of significant differences. As shown in Table 6, the ANOVA tests showed significant variations between grade levels for CK ($F = 4.036$, $p = 0.007$), PK ($F = 2.937$; $p = 0.033$), PCK ($F = 3.587$; $p = 0.014$), TPK ($F = 3.632$; $p = 0.013$), and TPCK ($F = 4.702$; $p = 0.003$); all were less than the 0.05 significance level. This indicates that the perceptions of MEd level students were greater compared to the perceptions of BEd level students for all TPACK dimensions. However, the subscale of TK did not differ significantly between grade levels ($F = 1.094$; $p = 0.351$). As for overall TPACK, pre-service teachers who were at the MEd level ($M = 4.430$; $SD = 0.378$) believed that they were more confident than those at the BEd level. Since several domains show significant differences, Tukey's HDS Post-hoc test was done.

Table 6. Comparison of TPACK Perceptions According to Grade Levels

Domains	Grade	*N*	Mean	SD	*F*	*p*	Post Hoc
TK	(1) 2nd Year BEd	105	4.133	0.507	1.094	0.351	
	(2) 3rd Year BEd	283	4.188	0.548			
	(3) 4th Year BEd	33	4.023	0.657			
	(4) MEd	60	4.142	0.442			
CK	(1) 2nd Year BEd	105	4.295	0.494	4.036	0.007	4>2
	(2) 3rd Year BEd	283	4.230	0.505			4>3
	(3) 4th Year BEd	33	4.142	0.640			
	(4) MEd	60	4.456	0.472			
PK	(1) 2nd Year BEd	105	4.493	0.476	2.937	0.033	4>3
	(2) 3rd Year BEd	283	4.461	0.516			
	(3) 4th Year BEd	33	4.280	0.752			
	(4) MEd	60	4.604	0.412			
PCK	(1) 2nd Year BEd	105	4.273	0.487	3.587	0.014	4>1
	(2) 3rd Year BEd	283	4.278	0.500			4>2
	(3) 4th Year BEd	33	4.212	0.656			4>3
	(4) MEd	60	4.495	0.462			
TPK	(1) 2nd Year BEd	105	4.331	0.505	3.632	0.013	4>3
	(2) 3rd Year BEd	283	4.245	0.497			
	(3) 4th Year BEd	33	4.103	0.803			
	(4) MEd	60	4.430	0.495			
TPCK	(1) 2nd Year BEd	105	4.267	0.492	4.702	0.003	3>1
	(2) 3rd Year BEd	283	4.172	0.504			4>3
	(3) 4th Year BEd	33	3.983	0.739			
	(4) MEd	60	4.362	0.502			
All Domains	(1) 2nd Year BEd	105	4.296	0.416	4.704	0.003	4>2
	(2) 3rd Year BEd	283	4.248	0.431			4>3
	(3) 4th Year BEd	33	4.098	0.639			
	(4) MEd	60	4.430	0.378			

According to the results, there was a significant gap between pre-service STEM teachers who were at the MEd level and those at the third-year BEd level ($p = 0.010$) and the fourth-year BEd level ($p = 0.024$) with respect to the CK domain. The results of the Post-hoc test also revealed a significant gap between pre-service teachers who were at the MEd level and those at the fourth-year BEd level ($p = 0.020$) with regard to the PK domain. Furthermore, in terms of PCK scores, the test revealed a significant gap between pre-service teachers who were at the MEd level and those at the second-year BEd level ($p = 0.035$) and the third-year BEd level ($p = 0.014$) and the fourth-year BEd level ($p = 0.049$). Moreover, there was a significant gap in TPK scores between pre-service teachers who were at the MEd level and those at the fourth-year BEd level ($p = 0.022$). Finally, the study showed a significant gap in TPACK scores between pre-service teachers who were at the MEd level and those at the fourth-year BEd level ($p = 0.005$) and between pre-service teachers who were at the fourth-year BEd level ($p = 0.014$) and second-year BEd level ($p = 0.033$).

To examine the relationship between variables, in accordance with the last research question, Pearson's linear correlation *r* coefficient was computed. The researchers also tested whether the grade level was related to TPACK. The results of the correlational analysis are displayed in Table 7.

Table 7. Correlations between Variables based on Pearson's Correlation Coefficient

	1	2	3	4	5	6	7	8
TK	1							
CK	0.509**	1						
PK	0.550**	0.611**	1					
PCK	0.536**	0.688**	0.670**	1				
TPK	0.589**	0.651**	0.686**	0.735**	1			
TPCK	0.531**	0.644**	0.629**	0.714**	0.819**	1		
All Domains	0.740**	0.820**	0.824**	0.860**	0.890**	0.860**	1	
Grade Level	-0.017	0.072	0.033	0.108*	0.031	0.023	0.058	1

Note: **$p < 0.01$; *$p < 0.05$

Based on Table 7, the correlations between the six TPACK factors were all highly positive. The results also suggested that there was a significant correlation between all TPACK perception domains ($p < 0.050$). It should be noted that the highest correlation appeared between TPK and general TPACK ($r = 0.890$; $p = 0.000$) and the lowest was between TK and CK ($r = 0.509$; $p = 0.000$). Additionally, the second-highest relationship was found both between PCK and all TPACK components ($r = 0.860$; $p = 0.000$) and also between TPCK and all TPACK domains ($r = 0.860$; $p = 0.000$) as these were higher than 0.50 recommended by Cohen (1988). According to the results, in general, the correlation coefficient between the remaining TPACK dimensions ranged from 0.531 to 0.824. Moreover, grade level was found to have a small and insignificant negative correlation with TK. Weak but not significant positive correlations were also found between grade level and CK, PK, TPK, TPCK, and all TPACK fields. Only the correlation between grade level and PCK was statistically significant. Considering these values, it may be inferred that pre-service teachers' perceptions of TPACK tend to be influenced by TPACK factors rather than grade level.

In the present study, pre-service STEM teachers' perceptions of technological pedagogical and content knowledge (TPACK) with regard to their gender, age, and grade level were investigated. According to the results, pre-service teachers rated themselves above four on a five-point scale, which indicates that the mean score is relatively high compared to the midpoint. It can be seen that pre-service teachers exhibit the highest self-confidence level in pedagogical knowledge. On the other hand, all participants had the lowest score in technological knowledge. In short, they were more knowledgeable in the area of pedagogy and content than in technology. This result is fully compliant with previous works (e.g., Schmidt et al., 2009; Koh et al., 2010; Roig-Vila et al., 2015). For instance, Bingimlas (2018) reported that the majority of participants rated themselves positively on average in terms of their level of confidence in TPACK and the highest and lowest levels of confidence are pedagogical knowledge and technological knowledge, respectively. In addition, Schmidt et al. (2009) analyzed the results from a pilot study on 124 pre-service teachers and reported that the TPACK scores of in-service teachers were greater than the neutral point. Supportively, they also found that TK scores were slightly lower than the other TPACK components. According to the results, there is an urgent need in teacher training programs to not only learn about pedagogy (PK) but also how to use technology (TK) to support content (CK) and how to integrate all three knowledge effectively in the curriculum.

As with prior literature of pre-service teachers (Lin et al., 2013; Cengiz, 2015; Luik et al., 2017; Bingimlas, 2018), in general, all participants were overwhelmingly positive in their perceptions of TPACK in this study. In a previous study, Luik et al. (2017) reported that in-service teachers' perceptions of TPACK tend to be slightly more positive. The fairly high mean scores in TPACK in this study may be related to pre-service STEM teachers' familiarity with the pedagogical approaches adopted in the classroom, the technology utilized in their daily lives, and the TPACK-based activities used in their teacher preparation programs. In addition, the curriculum of teacher education programs is quite comprehensive to improve pre-service teachers' all TPACK perceptions. Another possible reason why pre-service teachers have relatively high confidence in TPACK may be that access to technology in their college is adequate. Therefore, as technology continues to evolve rapidly, it is important for pre-service STEM teachers to keep up with new technologies and attend technology-related courses. It is

intended that they receive explicit instruction on subject-related technology to make it easier for their students to learn the subject they teach in the future.

The influence of pre-service teachers' gender on their TPACK self-confidence was explored. Overall, the results implied that there was no significant gap between pre-service teachers' TPACK and gender. This result echoes the previous literature (e.g., Koh & Sing, 2011; Altun & Akyıldız, 2017; Yildiz, 2017). For example, Koh and Sing (2011) analyzed the effect of age and gender on TPACK perceptions of Singaporean pre-service teachers and found that no significant gender differences were found across all TPACK dimensions. This is also in complete agreement with the work of Altun and Akyıldız (2017) who explored pre-service teachers' TPACK levels in terms of different variables and reported that there was no significant gap between gender and TPACK factors. This small difference in the current study may be because male and female pre-service teachers tend to feel comfortable in using technology (Le & Song, 2018). Another possible explanation may be that teacher training institutions provided pre-service STEM teachers with well-designed classes to prepare them for the future teaching profession (Saltan & Arslan, 2017).

As for all TPACK domains, it should be noted that female pre-service teachers feel more confident than males in the present study. Nevertheless, both male and female pre-service teachers' perceptions related to TPACK components are almost equivalent. Aligning with this result, Irmak and Tüzün (2018) highlighted that female pre-service science teachers were higher in PK, TCK, PCK, and TPACK than males. This result may be because females are more interested in using technology activities and possess more positive attitudes towards technology than males (Dhindsa & Shahrizal-Emran, 2011; Johnson, 2011). Moreover, the reason for the difference is mostly related to the difference between the way of thinking and the habit of studying (Wang et al., 2020). In a previous study, Wang et al. (2020) revealed that the majority of female students are at the top of the class, implying that they have better content knowledge than males. Based on the existing literature, the researchers predicted that the levels of interest and content knowledge of pre-service STEM teachers may cause differences in the TPACK scores. This may explain why female pre-service teachers' perceptions of the TPACK-related dimensions tend to be slightly higher than that of males in this study. Thus, in order to help male pre-service teachers improve their TPACK, teacher training programs should integrate new technologies into their instruction while building the link between knowledge of technology, content, and pedagogy in an integrated manner.

The effect of age groups (i.e., 20-22, 23-25, and over 25) on pre-service teachers' perceived TPACK domains was also examined. Unfortunately, the results did not reflect a significant gap. This result is similar to the findings of previous evidence. For instance, Koh & Sing (2011) and Çetin-Berber & Erdem (2015) mentioned that age may not be a factor that significantly affects pre-service teachers' perceptions of TPACK. Similarly, Koh et al. (2010) investigated the TPACK perceptions of Singaporean pre-service teachers and their relationship with their demographic factors. They found that the TPACK perceptions of pre-service teachers were not significantly different with regard to their age. However, the current study revealed that perceptions of pre-service teachers who are older than 25 years old were higher compared to those in 23-25 age group and in 20-22 age group. Similarly, Castéra et al. (2020) found a gradual increase in mean scores of subcomponents PK, CK, and PCK from the youngest to the oldest age groups. It means that older participants feel more competent in TPACK than younger participants. This may be due to the fact that participants who are older than 25 years old have attended some technology, content, and pedagogy-related courses more than those in 23-25 age group and in 20-22 age group. This could be the reason for the minor difference between older and younger pre-service teachers' TPACK in the current study.

The results of ANOVA also indicated that grade levels (i.e., 2nd year, 3rd year, 4th year BEd, and MEd) had a significant impact on pre-service teachers' TPACK scores. Statistically significant differences between grade levels have been found in favor of MEd level students. Not surprisingly, MEd level participants have higher perceptions related to CK, PK, PCK, TPK, TPCK, and all TPACK components. This finding is understandable and in line with previous evidence (e.g., Luik et al., 2017; Yildiz, 2017). In a quantitative study, Yildiz (2017) examined techno-pedagogical competencies of Turkish pre-service teachers with respect to some variables. He reported that there was a statistically significant gap in the techno-pedagogic competencies of pre-service mathematics teachers in relation to their grade level. Supportively, Çetin-Berber and Erdem (2015) also found that the self-confidence of fourth-year pre-service teachers was significantly

greater than second-year pre-service teachers in terms of PCK, and third-year pre-service teachers had significantly higher self-confidence than second-year pre-service teachers with regard to TCK. Additionally, Luik et al. (2017) explored the TPACK perceptions of Estonian pre-service teachers in terms of demographics and reported that all postgraduate students have rated all their TPACK perceptions significantly higher than undergraduate students for all factors. The reason for this finding might stem from the fact that pre-service STEM teachers who are at the MEd level have more practical opportunities to learn various instructional strategies and tend to employ more technological tools than those at the BEd level. In addition, at the MEd level, pre-service teachers study content, pedagogy, and technology for two years. In line with this result, Chuang and Ho (2011) concluded that teachers with more years of experience rated themselves higher on some sub-components of TPACK. This evidence supported why higher grade participants had more positive perceptions of TPACK than lower grade participants. Therefore, there is a crucial need to ensure that undergraduate education curricula offer more TPACK-related compulsory and elective courses.

Finally, the relationships among the components of the TPACK were investigated. Based on the results of Pearson's correlation analysis, all the TPACK dimensions were positively correlated with each other and all interrelationships are statistically significant. In addition, grade-level variables were generally associated with higher TPACK scores. In brief, an increase in technological, pedagogical, and content knowledge and its intersection with other knowledge components is linked to an increase in TPACK knowledge. These results are in accordance with previous literature (e.g., Koh & Sing, 2011; Alpaslan et al., 2021) which reported a positive and significant relationship between the TPACK components. In addition, in Roig-Vila et al.'s (2015) study, they have found statistically significant correlations among all dimensions of TPACK. One explanation for this finding could be that the more experiences of MEd level students related to the use of technology tools, application of pedagogy approaches, and mastery of content have a positive effect on their self-confidence towards TPACK. In essence, a higher grade level affects students' confidence in TPACK. It was clear that pre-service teachers who are more knowledgeable about technology may be more likely to use technology tools for subject-related purposes, thereby increasing their knowledge of pedagogy and content as well as their interaction with technology efficiently. Not surprisingly, pre-service STEM teachers in higher grades tended to have greater mean TPACK scores than those in lower grades in this survey. The results indicated that pre-service STEM teachers need to be provided with quality teacher education programs aimed at improving their perceived TPACK, such as how to use ICT appropriately, choose effective pedagogical strategies, and master content knowledge related to their subjects.

CONCLUSION

In sum, the current study provided information on the TPACK levels of Indonesian pre-service teachers. The researchers highlighted that pre-service STEM teachers seem to have a fairly high perception of all six TPACK fields. Furthermore, all participants had more pedagogical and content knowledge than technological knowledge. However, there were no statistically significant gaps in TPACK with respect to gender and age group. The difference was only found in terms of grade level. This reflects that the higher the grade level, the higher the TPACK perceptions. Moreover, a positive and significant correlation was reported between the six TPACK factors. Surprisingly, male pre-service teachers perceived their TPACK lower than females, which means that females consider themselves more confident and knowledgeable than males in this field. This implies that male pre-service teachers need more support for TPACK domains. To promote technological knowledge among students, especially male students, the number of technology-related elective courses should be increased. The researchers assume that when pre-service teachers take technology-related courses and they get high grades in these courses, their technological knowledge is likely to be higher. Prior literature confirmed that the effective application of technology in teacher education programs plays a fundamental role in preparing students for their technology-enriched classrooms in the future. Unfortunately, in Indonesia, courses related to technology, content, and pedagogy are generally offered separately. As a suggestion, instead of providing separate technology, content, and pedagogy courses, there is a need to design courses in teacher preparation programs to enhance pre-service teacher TPACK in an integrated manner. Thus, lecture-based teaching should be reduced and more TPACK-related activities should be well-prepared in Indonesian teacher education institutions. More importantly, students should have more opportunities to apply this knowledge. This suggests

that more efforts need to be taken to enhance the interaction between pedagogy, technology, and content knowledge. Briefly, teacher education programs in Indonesia should integrate technology and pedagogy into classrooms to enhance content knowledge and support the intersection of other knowledge domains.

REFERENCES

Adamy, P., & Boulmetis, J. (2006). The impact of modeling technology integration on pre-service teachers' technology confidence. *Journal of Computing in Higher Education, 17*(2), 100–120.

Alpaslan, M. M., Ulubey, O., & Ata, R. (2021). Adaptation of technological pedagogical content knowledge scale into Turkish culture within the scope of 21st century skills. *Psycho-Educational Research Reviews, 10*(1), 77–91.

Altun, D. (2019). Investigating pre-service early childhood education teachers' technological pedagogical content knowledge (TPACK) competencies regarding digital literacy skills and their technology attitudes and usage. *Journal of Education and Learning, 8*(1), 249–263.

Altun, T., & Akyıldız, S. (2017). Investigating student teachers' technological pedagogical content knowledge (TPACK) levels based on some variables. *European Journal of Education Studies, 3*(5), 467–485.

Bingimlas, K. (2018). Investigating the level of teachers' knowledge in technology, pedagogy, and content (TPACK) in Saudi Arabia. *South African Journal of Education, 38*(3), 1–12.

Castéra, J., Marre, C. C., Yok, M. C. K., Sherab, K., Impedovo, M. A., Sarapuu, T., Pedregosa, A. D., Malik, S. K., & Armand, H. (2020). Self-reported TPACK of teacher educators across six countries in Asia and Europe. *Education and Information Technologies, 25*, 3003–3019.

Cengiz, C. (2015). The development of TPACK, technology integrated self-efficacy and instructional technology outcome expectations of pre-service physical education teachers. *Asia-Pacific Journal of Teacher Education, 43*(5), 411–422.

Cetin-Berber, D., & Erdem, A. (2015). An investigation of Turkish pre-service teachers' technological, pedagogical and content knowledge. *Computers, 4*(3), 234–250.

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2016). A review of the quantitative measures of technological pedagogical content knowledge (TPACK). In M. C. Herring, M. J. Koehler, and P. Mishra, *Handbook of Technological Pedagogical Content Knowledge (TPACK) for Educators* (pp. 87–106). Routledge.

Chuang, H., & Ho, C. (2011). An investigation of early childhood teachers' technological pedagogical content knowledge TPACK in Taiwan. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi, 12*(2), 99–117.

Cohen, J. W. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.

Dhindsa, H. S., & Shahrizal-Emran (2011). Using interactive whiteboard technology-rich constructivist learning environment to minimize gender differences in chemistry achievement. *International Journal of Environmental & Science Education, 6*(4), 393–414.

Evans, J. R., & Mathur, A. (2005). The value of online surveys. *Internet Research, 15*(2), 196–219.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. (2019). *How to design and evaluate research in education* (10th ed.). McGraw-Hill.

Gómez-García, G.; Hinojo-Lucena, F.-J.; Alonso-García, S.; Romero-Rodríguez, J.-M. (2021). Mobile learning in pre-service teacher education: Perceived usefulness of ar technology in primary education. *Education Sciences, 11*, 275.

Irmak, M., & Tüzün, O. Y. (2018). Investigating pre-service science teachers' perceived technological pedagogical content knowledge (TPACK) regarding genetics. *Research in Science & Technological Education, 37*(2), 127–146.

Irwanto, I. (2021). Research trends in technological pedagogical content knowledge (TPACK): A systematic literature review from 2010 to 2021. *European Journal of Educational Research, 10*(4), 2045–2054.

Jamieson-Proctor, R., Finger, G., & Albion, P. (2010). Auditing the TK and TPACK confidence of pre-service teachers: Are they ready for the profession?. *Australian Educational Computing, 25*(1), 8–17.

Johnson, R. D. (2011). Gender differences in e-learning. *Journal of Organizational and End User Computing, 23*(1), 79–94.

Kartimi, K., Gloria, R., & Anugrah, I. (2021). Chemistry online distance learning during the Covid-19 outbreak: Do TPACK and teachers' attitude matter?. *Jurnal Pendidikan IPA Indonesia, 10*(2), 228–240.

Keser, H., Yılmaz, F. G. K., & Yılmaz, R. (2015). TPACK competencies and technology integration self-efficacy perceptions of pre-service teachers. *Elementary Education Online, 14*(4), 1193–1207.

Khine, M. S., Ali, N., & Afari, E. (2016). Exploring relationships among TPACK constructs and ICT achievement among trainee teachers. *Education and Information Technologies, 22*(4), 1605–1621.

Koh, J. H. L. & Sing, C. C. (2011). Modeling pre-service teachers' technological pedagogical content knowledge (TPACK) perceptions: The influence of demographic factors and TPACK constructs. In G. Williams, N. Brown, M. Pittard, & B. Cleland (Eds.), *Changing Demands, Changing Directions* (pp. 735–746). ASCILITE.

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

Assisted Learning, 26(6), 563–573.

Koyuncuoğlu, O. (2021). An investigation of graduate students' technological pedagogical and content knowledge (TPACK). *International Journal of Education in Mathematics, Science, and Technology*, *9*(2), 299–313.

Krauskopf, K., & Forssell, K. (2018). When knowing is believing: A multi-trait analysis of self-reported TPCK. *Journal of Computer Assisted Learning, 34*(5), 482–491.

Le, N., & Song, J. (2018). TPACK in a CALL course and its effect on Vietnamese preservice EFL teachers. *Asian EFL Journal, 9*(1), 31–56.

Lin, T.-C., Tsai, C.-C., Chai, C. S., & Lee, M.-H. (2013). Identifying science teachers' perceptions of technological, pedagogical, and content knowledge (TPACK). *Journal of Science Education and Technology*, 22, 325–336.

Luik, P., Taimalu, M., & Suviste, R. (2017). Perceptions of technological, pedagogical and content knowledge (TPACK) among pre-service teachers in Estonia. *Education and Information Technologies, 23*(2), 741–755.

Lux, N. J., Bangert, A. W., & Whittier, D. B. (2011). The development of an instrument to assess preservice teacher's technological pedagogical content knowledge. *Journal of Educational Computing Research, 45*(4), 415–431.

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

Muhaimin, M., Habibi, A., Mukminin, A., Saudagar, F., Pratama, R., Wahyuni, S., Sadikin, A., & Indrayana, B. (2019). A sequential explanatory investigation of TPACK: Indonesian science teachers' survey and perspective. *Journal of Technology and Science Education, 9*(3), 269–281.

Özçakır, B., & Aydın, B. (2019). Effects of augmented reality experiences on technology integration self-efficacy of prospective mathematics teachers. *Turkish Journal of Computer and Mathematics Education, 10*(2), 314–335.

Pallant, J. (2020). *SPSS survival manual: A step by step guide to data analysis using IBM SPSS* (7th ed.). Routledge.

Robson, C., & McCartan, K. (2015). *Real-world research* (4th ed.). Wiley.

Roig-Vila, R., Mengual-Andrés, S., & Quinto-Medrano, P. (2015). Primary teachers' technological, pedagogical and content knowledge. *Comunicar, 23*(45), 151–159.

Saltan, F., & Arslan, K. (2017). A comparison of in-service and preservice teachers' technological pedagogical content knowledge self-confidence. *Cogent Education, 4*(1), 2–13.

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK). *Journal of Research on Technology in Education, 42*(2), 123–149.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14.

Turgut, Y. (2017). Tracing preservice English language teachers' perceived TPACK in sophomore, junior, and senior levels. *Cogent Education, 4*(1), 2–21.

Wang, Y. X., Gu, X. M., & Liu, S. F. (2020). The investigation and analysis of pre-service teachers toward TPACK competencies. *Open Journal of Social Sciences, 8*(12), 327-339.

Yildiz, A. (2017). The factors affecting techno-pedagogical competencies and critical thinking skills of preservice mathematics teachers. *Malaysian Online Journal of Educational Sciences, 5*(2), 66–81.