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Cambodian STEM pre-service teachers' competency in effective information communication technology integration teaching based on technological pedagogical content knowledge framework

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Abstract: This study explores how Cambodian STEM (Science, Technology, Engineering, and Mathematics) pre-service teachers comprehended the Technological Pedagogical Content Knowledge (TPACK) and its components, content knowledge (CK), pedagogical knowledge (PK), technological knowledge (TK), pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), technological content knowledge (TCK) and their associations with demographic variables. Using a self-report questionnaire, the study surveyed 440 pre-service teachers from three distinct teacher training colleges. Data was analyzed using descriptive statistics, independent *t*-test, and Pearson's correlation. Results showed that pre-service teachers rated themselves above the mean in all components: TPK and CK were the highest, and TCK and TPACK were the lowest. There was a significant difference in the gender and foreign language variables; males and being able to understand foreign languages were the favor. A negative relationship existed in age variables where younger pre-service teachers demonstrated higher competence in all aspects of TPACK except PCK. It concluded that Cambodian STEM pre-service teachers demonstrate adequate knowledge of content, pedagogy, and technology to integrate information communication and technology (ICT) into their teaching. Possessing a medium to a high level of TPACK, additional professional development programs are needed to assist pre-service teachers in reaching the highest TPACK level.

Keywords: Cambodian education; educational technology; science education; science teacher; TPACK.

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INTRODUCTION

Rapid technological advancements have spurred an increased demand for high science and technology competencies. To cultivate a high level of STEM competencies in students, teachers and pre-service teachers must transition from traditional knowledge dissemination to a more dynamic approach that leverages technology and pedagogy to engage students actively in constructing their knowledge (Dorsah, 2021; Syukri, Yulisman, & Nurina, 2020). Zulkifli, Satria, Supriyadi, and Santosa (2022) have revealed that technology-based learning can enhance critical thinking skills in students and help them apply their knowledge of STEM to solve problems in daily life.

Following this revolution, Cambodia's education system ambitiously aims to educate digital citizens by integrating digital education and fostering the implementation of STEM education from the secondary level

(MoEYS, 2021). With this aim, the Ministry of Education, Youth, and Sports (MoEYS) has taken several actions. It included developing an ICT education policy and projects, equipping and providing computer labs and ensuring internet access to targeted schools, and implementing technology for education syllabus into teachers' training programs. With this effort, MoEYS believed that teachers and pre-service teachers could select a particular technology to represent the content subject suitable for asynchronous learners to enhance student 21st-century skills.

The effort made by MoEYS had less fruitful results; according to the latest statistic available, only five percent of upper secondary school teachers utilized technology as a supporting tool in the education environment until the COVID-19 period (MoEYS, 2019). The COVID-19 pandemic has boosted the utilization of ICT in teaching and learning practice (Heng, 2021; Thy, Ly, & Ean, 2023). However, teachers addressed many challenges, including issues related to their competency in using ICT for teaching and related tasks (Thy, Ly, et al., 2023). Specifically regarding science, a study by Thy, Ann, Pen, and Khek (2023) highlighted that Cambodian high school science teachers have demonstrated confidence in leveraging online platforms like Zoom, Google Classroom, and other applications to facilitate distance learning and administrative tasks. On the other hand, the study also revealed a pressing need for additional support in effectively conveying subject matter to students through accessible technology. Thy, Im, and Iwayama (2023) found that Cambodian science teachers exhibited satisfactory foundational ICT skills for administrative tasks, social communication, and professional growth. However, they encountered challenges in utilizing ICT effectively to enhance teaching methods and elevate student learning outcomes. Only one-third demonstrated awareness of various ICT technologies for subject instruction, and less than 25% felt confident employing online learning platforms to deliver lessons. Regarding proficient computer use, a mere one-fifth of teachers believed in their capability (Thy, 2024).

Mishra and Koehler (2006) proposed TPACK as a framework to access teachers' competencies for effective technology integration in a classroom setting. This framework included technology into the Shulman (1986) PCK original framework. With this integration, teachers need to have enough knowledge of three fundamental knowledge —technology, content, and pedagogy—and their intersections are known as PCK, TCK, TPK, and TPACK (Koehler & Mishra, 2009; Koh, Chai, & Tsai, 2013; Tondeur, Scherer, Siddiq, & Baran, 2020). In Mishra and Koehler's framework (2006), technology is not restricted to any specific technology; however, in this study, the authors refer specifically to ICT. Teachers who have a high level of TPACK seem to be advanced in designing lessons that successfully integrate ICT in their teaching to enhance students' learning activities (Chai et al., 2013; Stinken-Rösner et al., 2023; Yanti et al., 2020). This framework is not limited to analyzing the teacher's proficiency to integrate ICT in their teaching practice effectively and is utilized to design teacher education curricula and professional development programs (Archambault & Crippen, 2009; Herring et al., 2016; Schmidt et al., 2009). To ensure the effectiveness of

ICT integration in educational practice, therefore, pre-service teachers' TPACK competencies could be employed as a benchmark for evaluation criterion (Koehler et al., 2013; Mishra & Koehler, 2006).

The TPACK framework has been created to assist teachers in comprehending the necessary knowledge they require to effectively incorporate technology in their classrooms, as well as how to acquire that knowledge and how it impacts their overall TPACK (Pamuk, 2012; Wang et al., 2018). It is imperative to employ this framework to evaluate teachers' extensive TPACK and any factors that may influence their proficiency. Despite numerous studies exploring pre-service teachers' TPACK abilities and their potential correlation with demographic variables such as gender and age, the relationship between these variables and TPACK remains unclear.

Recent studies by Irwanto, Redhana, and Wahono (2022), Schmid, Brianza, and Petko (2021), and Altun and Akyildiz (2017) indicated no significant gender difference in all TPACK components, except for PK, in which females tend to outperform males. Conversely, Luik, Taimalu, and Suviste (2018) and Ergen, Yelken, and Kanadli (2019) have exposed a significant difference in TPACK competencies based on gender, with males favored over their counterparts.

Age is also found to have an unpredictable association with teachers' TPACK perception, particularly in technology-related domains. Irwanto et al. (2022), Schmid et al. (2021), and Koh, Chai, and Tsai (2014) reported no significant difference regarding age groups in all TPACK components. Contrastingly, Luik et al. (2018) and Koh, Chai, and Tsai (2010) indicated that age has a negative relationship with teachers' TPACK perception in technology-related aspects, with no relation in pedagogy but a positive relation in content knowledge.

Despite the plethora of studies exploring the perceptions of pre-service educators regarding TPACK and factors influencing TPACK levels in teacher education programs, most contributors have been from the United States, Turkey, Australia, Singapore, and Taiwan, respectively (Irwanto, 2021). Alongside this, many studies have demonstrated that the TPACK competency varied across different contexts and cultures, emphasizing the need for further research from various perspectives to ensure the valid and reliability of this framework (Jang & Chen, 2010; Koh et al., 2013; Schmid et al., 2020).

Through the lens of the Technological Pedagogical Content Knowledge framework, the Cambodian context has seen limited studies. One notable instance is the research conducted by Chea, Bo, and Minami (2022), which employed the TPACK framework to investigate teacher readiness for remote learning during the COVID-19 pandemic. The findings indicated that high school teachers exhibit elevated confidence levels in PCK followed by PK, CK, and technology-related proficiency, with TK registering as the least confident domain. Furthermore, a noteworthy distinction emerged between male and female teachers, with male teachers rating themselves more favorably than their counterparts. A fascinating observation pertains to the paradox of teachers who have received ICT training, a better ICT infrastructure, and access to more resources yet demonstrate lower knowledge in technology-related domains compared to teachers in ordinary

schools. This disparity prompted Thy, Im, et al. (2023) to examine the TPACK of science high school teachers, encompassing an additional school category, New Generation Schools (NGS). In this expanded study, all the TPACK components surpassed the media score, with teachers expressing greater confidence in CK and diminished confidence in technology-related domains. This study did not prove a significant gender difference but indicated a negative relationship between teacher age and teaching experience.

Furthermore, teachers from rich infrastructure related to ICT are more confident than those from ordinary schools. As a result, in Cambodia, those studies showed contrasting results in some domains and related variables; thus, more studies are needed to explore the TPACK framework and how it is associated with demographic variables. Both studies were exclusively conducted with high school teachers; consequently, there remains a gap in understanding how pre-service teachers score their TPACK.

Language barriers have been indicated as the factors that influence ICT implementation in the classroom where English is not the first language, as around 80% of software and content is written in English (Basargekar & Singhavi, 2017; Salam et al., 2018). It is noteworthy that Cambodia, a developing nation, actively engages as a consumer of various ICTs. In this context, the Khmer language assumes a peripheral role when interfacing with ICTs, with foreign languages, mainly English, assuming paramount importance for effective communication and utilization of ICT resources. Consequently, individuals within Cambodia who possess proficiency exclusively in the Khmer language face limitations and reduced opportunities for ICT engagement. Conversely, those equipped with proficiency in English are inclined to engage more extensively and effectively with ICTs. Against this backdrop, the author posits a hypothesis suggesting that competence in English and other foreign languages significantly influences teachers' aptitude for integrating ICTs into their pedagogical practices.

Based on the literature, the TPACK framework is an appropriate criterion for assessing pre-service teachers' competency in integrating ICT into their future classes. Thus, this study explores Cambodian STEM pre-service teachers' competencies in effective ICT integration teaching based on the TPACK framework and its relationship with demographic variables, gender, age, and foreign language proficiency. These findings contribute to the literature on TPACK in different contexts, highlighting contradictions in gender and age. Notably, the study introduces a novel factor, the influence of a foreign language, which has not been investigated in the previous literature. This factor may impact the TPACK aptitude of pre-service teachers, particularly in countries like Cambodia, where ICT is widely used. At this point, competencies refer to the aptitude of pre-service teachers to comprehend a key concept in content, pedagogy, and technology and their intersections. The current study wishes to answer the following questions:

1. What is Cambodian STEM pre-service teachers' TPACK competencies?
2. Is there any significant difference in TPACK competencies based on gender, and knowledge of foreign languages?
3. What is the relationship between age and TPACK competencies?

METHOD

Design

The study utilized a survey research design to obtain data from the participants. This type of design is frequently used to depict a particular population's trait or an occurrence in their environment without changing any variables that could affect the outcomes (Gay, Mills, & Airasian, 2012).

Participants

The study comprised 440 Cambodian STEM pre-service teachers in Cambodia, hereafter referred to as pre-service teachers, with 286 of them being female. These individuals were enrolled in three distinct teacher training colleges, as shown in Table 1. Notably, 95 participants (constituting 21.6% of the total) were affiliated with the National Institute of Education (NIE), the sole teacher training institution in Cambodia offering the high-education certificate program. Participants, 181 (41.2%) were from the Phnom Penh Teacher Education College (PTEC), while the remaining 164 (37.2%) were from Bambang Teacher Education College (BTEC) and will be lower secondary high school teachers upon graduation. The participants ranged from 18 to 42 years old (M=22.93, SD=3.37).

Table 1. The Participants' Demographics

		Male (%)	Female (%)	Subtotal (%)
Training program	NIE	45 (10.2)	50 (11.4)	95 (21.6)
	PTEC	53 (12.1)	128 (29.1)	181 (41.2)
	BTEC	56 (12.7)	108 (24.5)	164 (37.2)
Foreign Language	No	20(4.54)	45(10.23)	65(14.77)
	Yes	134(30.46)	241(54.77)	375(85.23)
Total		**154 (35.0)**	**286 (65.0)**	**440 (100)**

Data collection procedure

The participants in this study were voluntary, despite the consent form being sent to each teacher training college. Pre-service teachers were given the TPACK questionnaire, which took approximately 15-20 minutes to complete. Although the survey was accessed through Google Forms, researchers clarified the purpose of the study and response procedure. They addressed any misunderstanding in the questionnaire face-to-face to enhance the validity of the data obtained. To ensure the accuracy of self-reported assessment data, researchers encourage respondents to be truthful and mention that participants' responses will not bear their grades or studies, but it would aid in identifying the current situation in the teacher education program.

Instrument

A survey research method explored how pre-service teachers comprehend the TPACK. The questionnaire consists of two sections; the first section was about demographic information (i.e., affiliation, age, gender, and knowledge of foreign language). The second section consists of 35 items in seven

components of TPACK, and Table 2 presents the number of items in each component. The TPACK instrument was adopted by Schmid et al. (2020) and added seven more items to the original survey. These items have been successfully validated in the Cambodian context as they have been used in previous studies (Chea et al., 2022; Thy, Im et al., 2023). Each item in the survey employed a five-point Likert scale, with 1= strongly disagree, 2 = disagree, 3= neutral, 4 = agree, and 5 = strongly agree. After being translated into the Cambodian language, the instrument was reviewed and consulted with the expert and science educators at the NIE to enhance the content validity.

Since the instrument integrated adopted items contextualized to the Cambodian context, Principal Component Analysis (PCA) with Varimax Rotation was conducted to evaluate the internal structure of TPACK. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.97, surpassing the acceptable level of 0.80. Furthermore, Bartlett's test of sphericity was significant ($\chi 2(595) = 9786.87$, $p < .001$), affirming the suitability of the data for factor analysis. Subsequently, we confirmed the components with eigenvalues exceeding one, and the factor solution yielded four factors that accounted for 59.91% of the data variation. The instrument's reliability was determined on the overall and seven subscales of TPACK. The internal consistency reliability (Cronbach's alpha) was 0.97 for the overall domains and ranged from 0.78 to 0.85 for the subdomains (Table 2).

Data analysis

After exporting the raw data from Google Forms to a Microsoft Spreadsheet, the data was cleaned and coded to numeric before importing it into the data editor of Statistical Package for Social Science (SPSS) software version 23. Thirty-five scale items were converted to numeric data: strongly disagree is one, disagree is two, agree nor disagree is three, agree is four, and strongly agree is five. The data were analyzed using descriptive statistics to establish the teacher's current level of TPACK for answering research question 1. The level of TPACK is interpreted in five levels of mean: Highest (4.51-5.00), High (3.51-4.50), Medium (2.51-3.50), Low (1.51-2.50), and Lowest (1.00-1.50) (Nuangchalerm, 2020). Independent samples T-test was employed to investigate the relationship between gender and knowledge of foreign language variables and TPACK competency to answer research question 2. Pearson's correlation was utilized to identify the relationship between age and TPACK levels to answer research question 3.

RESULTS AND DISCUSSION

This study aimed to explore pre-service teachers' TPACK competencies. Therefore, the descriptive statistics of each of the seven and overall domains were determined. Pre-service teachers perceived self-confidence as a high level in overall domains, and the higher rated is in TPK (M = 3.69, SD = 0.60) and CK (M = 3.65, SD = 0.54). They rated lower scores in TCK (M=3.50, SD = 0.64) and TPACK (M=3.50, SD = 0.56), as indicated in Table 2.

Table 2. Descriptive statistics of the seven TPACK knowledge domains

	Number of Items	Mean (*N* = 440)	Standard Deviation	Cronbach's Alpha
CK	4	3.65	0.54	0.78
PK	5	3.62	0.55	0.80
TK	7	3.61	0.56	0.85
PCK	5	3.60	0.56	0.83
TCK	4	3.50	0.64	0.85
TPK	5	3.69	0.60	0.83
TPACK	5	3.50	0.56	0.80
Overall	35	3.60	0.51	0.97

The independent t-test results are indicated in Table 3. The calculation of the two groups' mean indicates that the average score of males is higher than females in all domains and overall domains. The gender is significantly different in CK, TK, PCK, TCK, TPK, TPACK, and overall domains, with the effect size (Cohen's d) of less than 0.5, as indicated in Table 3, revealing a relatively modest impact of gender differences in these constructs.

Table 3. Different TPACK levels between gender

	Male (M/SD) N=154	Female (M/SD) N=286	t-value	Effect size (Cohen's d)
CK	3.73 (0.58)	3.61 (0.51)	2.15*	0.22
PK	3.69 (0.58)	3.59 (0.53)	1.80	-
TK	3.73 (0.61)	3.55 (0.53)	3.06**	0.30
PCK	3.76 (0.55)	3.53 (0.56)	4.17**	0.41
TCK	3.59 (0.71)	3.45 (0.59)	2.14*	0.20
TPK	3.77 (0.63)	3.65 (0.57)	1.98*	0.19
TPACK	3.60 (0.59)	3.45 (0.54)	2.62**	0.25
Overall	3.69 (0.54)	3.55 (0.48)	2.87**	0.27

*Note: **p < .01, *p < .05*

As indicated in Table 4, the participants who understand foreign languages score higher than their counterparts. A significant difference was found in the technology-related domain: TK, TCK, TPK, TPACK, and overall domains with an effect size (Cohen's D) of less than 0.5, as indicated in Table 4, revealing a relatively modest impact of foreign language differences in these constructs.

Table 4. Different TPACK levels between knowledge of foreign language

	Yes (M/SD) N=375	No (M/SD) N=65	t-value	Effect size (Cohen's d)
CK	3.67 (0.55)	3.57 (0.45)	-1.40	-
PK	3.64 (0.56)	3.53 (0.45)	-1.45	-
TK	3.64 (0.58)	3.46 (0.43)	-2.94**	0.35
PCK	3.62 (0.57)	3.54 (0.54)	-1.04	-
TCK	3.52 (0.65)	3.36 (0.53)	-2.22*	0.26
TPK	3.72 (0.60)	3.52 (0.52)	-2.63**	0.37
TPACK	3.54 (0.57)	3.28 (0.45)	-4.01**	0.50
Overall	3.62 (0.52)	3.46 (0.41)	-2.29*	0.34

*Note: **p < .01, *p < .05*

Pearson's correlation coefficient was used to explain the relationship between the pre-service teacher's age and TPACK domains. The correlation results presented in Table 5 indicate a weak negative association between age (range from 18-42 years old) and six out of seven TPACK domains, with the exception being PCK.

Table 5. Correlations among seven TPACK domains, and age

	CK	**PK**	**TK**	**PCK**	**TCK**	**TPK**	**TPACK**	**Overall**
Age	-0.12*	-0.11*	-0.18**	-0.08	-0.23**	-0.21**	-0.16**	-0.18**

*Note: **p < .01, *p < .05*

According to the results in Table 2, pre-service teachers have shown a high knowledge of integrating ICT into the classroom by rating themselves above three on the five-point Likert scale (above the mean of the scale). It indicated that they possess confidence in applying technology to implement teaching strategies (TPK) and have significant knowledge of their subject and pedagogy (CK and PK). The teacher education program has provided pre-service teachers with the necessary skills to integrate ICT into their teaching practice. However, including technology in the classroom is more complex and requires more practice and guidance from the instructor, particularly for technology-related domains (Hsu, 2015; Tondeur et al., 2020; Valtonen et al., 2019). As a result, pre-service teachers rated themselves lowest in TCK and TPACK domains, which indicated a medium level. They may have challenges in representing subject content with technology, keeping updated with the ICT development in their subject (TCK), and selecting an appropriate pedagogy and technology to exhibit the subject matter (TPACK) accessible to asynchronous learners. Similar results were found in the studies of Irwanto et al. (2022) and Omoso & Odindo (2020), where pre-service teachers rated high in TPK and low in TCK. Contrarily, in a study by Saltan and Arslan (2017), pre-service teachers were found to have high TCK and low TPACK ratings.

In the second research question, the study investigated the difference in pre-service teachers' TPACK competencies in gender variables. A significant difference was found between gender variables and TPACK competencies, and males are in favor. It means male pre-service teachers are more confident in including technology in their teaching environment than their counterparts, except in PK. This finding aligns with the study of Ergen et al. (2019), who conducted a meta-analysis method in gender variables and found a significant difference in which males favor TK, TPK, and TPACK. Supportively, Chea et al. (2022) noticed a similar finding that male teachers rated themselves higher in all TPACK components. In Cambodia, this difference may relate to the characteristic that males are more likely interested in ICT than females. Contrarily, Irwanto et al. (2022), Schmid et al. (2021), and Altun and Akyildiz (2017) found no significant difference between males and females for all domains except in PK, where females showed more competence than males. Similarly, no significant difference was observed in gender in the study of Thy, Im, et al. (2023).

Foreign language proficiency is a curious variable that contributes to TPACK competencies. There was a significant difference in foreign language proficiency, and pre-service teachers who understood foreign languages tended to score higher in all TPACK domains. Although there is no literature to compare with this finding, this result is particularly relevant in Cambodia, where foreign language, mainly English usage, is crucial for effective communication and utilization of ICT resources. Most ICTs, such as programming, application, and simulation, are primarily operated in English, meaning those who need to be proficient in foreign languages may miss out on opportunities and incentives to develop ICT skills and integrate ICT into their teaching practices. However, further research is necessary to explore this variable since the sample size of those who understand and misunderstand foreign languages is highly different.

Table 5 indicated that younger pre-service teachers exhibit higher confidence in technology-related domains than older pre-service teachers, suggesting that the younger are more exposed to technology and stay up-to-date with the ICTs. However, there was no relationship in age regarding PCK, which implied that both younger and older pre-service teachers possess similar knowledge to choose appropriate teaching methods to help learner construct their knowledge. This finding aligns with the research conducted by Chea et al. (2022) and Thy, Im, et al. (2023), who found a negative relationship between technology-related domains except CK, PK, and PCK. In terms of age, Luik et al. (2018) discovered a positive correlation with content, no correlation with pedagogy, and a negative correlation with technology knowledge. However, this result is argued with the study of Irwanto et al. (2022), who found no relationship between age and TPACK level.

CONCLUSION

This study aims to explore the Cambodian STEM pre-service teachers' TPACK competencies and their association with demographic variables. The results revealed that pre-service teachers have adequate knowledge of TPACK. Pre-service teachers demonstrate sufficient knowledge of content, pedagogy, and technology to integrate ICT into their teaching and administrative tasks.

The study found a statistical difference in gender and foreign language proficiency in almost all the TPACK components. Male pre-service teachers are deemed more confident and knowledgeable than females overall and in all TPACK components. Additionally, pre-service teachers who understand foreign languages have higher competency in TPACK than those who do not. The study also found a weak negative correlation between age and TPACK levels. Older pre-service teachers have low competency in all TPACK domains except PCK.

Possessing a medium to a high level of TPACK, additional professional development programs are needed to assist pre-service teachers in reaching the highest TPACK level. Teacher training programs should consider designing courses integrating content, pedagogy, and technology instead of providing them separately to promote digital education. The training program has a potential influence on teachers' application of ICT in the classroom. Literature shows that pre-service teachers need proper training and

teaching models from their instructors to integrate technology into their future classrooms more effectively. For teacher training programs and professional development, female and non-foreign language proficient pre-service teachers need more support in almost all TPACK domains.

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