Examınıng the Teacher Candıdates' TPACK Competences: Evıdence From Four Teacher Educatıon Programs

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This study examined the valid items in the perception of TPACK competencies of physics, math, biology, and chemistry teacher candidates in one public university in Indonesia. This study used a cross-sectional survey where data were collected once from one sample at a time. The study was conducted in four teacher education programs in one public university. This study used a stratified proportioned random sampling technique. The sample for this study consisted of 400 students from 4 teacher education programs including Physics Education, Chemistry Education, Biology Education, and Mathematics programs. Data were collected through a questionnaire with 75 statements related to TPACK competency indicators. The data were processed and analyzed through Partial Least Squares Structural Equation Modeling (PLS-SEM) and by using SmartPLS 3.0 software. The results showed that of 75 statements, there were 27 valid statements related to TPACK competency indicators. These 27 statements can potentially be used to measure TPACK competencies of teacher candidates. The results obtained from the factor analysis and the Smart PLS procedures showed that the construction of items in the instrument and their relevance to each other is appropriate. Based on the overall results, one of the main findings of this study is that the predictive power of the core knowledge base and the second-level knowledge base on TPACK development is significantly different.

Keywords: prospective teachers, TPACK competencies, technology integration, teachers' knowledge

INTRODUCTION

The modern educational process should undergo continuous development and change, along with the teachers and pupils who are affected by such changes (Habibi, Sofyan, & Mukminin, 2023; Mukminin et al., 2023; Troselj et al., 2021). Studies on technology integration conducted in different environments have resulted in a common consensus that technology integration into teaching and learning is multifaceted and a complex process (Habibi et al., 2022; Susanti, Hadiyanto, & Mukminin, 2022; Mishra & Koehler, 2006). TPACK has now been implemented in different settings, either for the development of technology-based teaching activities or the assessment of technology integration of teachers' knowledge and experience (e.g., Agyei & Voogt, 2012; Koh et al., 2010; Koehler et al., 2007; Graham et al., 2009). This is especially important in a period of rapid change when new knowledge is not only added to the existing corpus but is replacing old paradigms, new technologies are replaced even before they have been fully explored, and the teacher must be prepared for and flexible in adapting to these changes (Dolenc et al., 2021). In this study, we explored the competence of TPACK for physics, math, biology, and chemistry teacher candidates in one public university in Indonesia. To achieve the study's objectives, first, we discussed the instrument adapted from Baran et al. (2014) and the validation of instruments specifically designed to measure teachers' technology integration knowledge and experience as described in the TPACK framework.

The TPACK framework of Pamuk et al. (2015) includes CK which is a subject matter that must be learned/taught where teachers need to have a deeper understanding of facts, concepts, theories, and procedures (Mishra & Koehler, 2006; Koehler et al., 2007; Koh et al., 2010). PK is the principles and strategies of teaching, learning, classroom management, student assessment, motivation, and all other teaching and learning issues (Mishra & Koehler, 2006; Shulman & Bernard, 1986; Gudmundsdottir & Shulman, 1987). Next, TK is related to all tools, materials, and technical skills used in the teaching and learning processes. TK includes the latest digital technologies (software and hardware) as well as old technologies (books, chalk, whiteboards, etc.), teachers in the TPACK framework are expected to know about the given technology and can use them in the classroom (Graham et al., 2009; Mishra & Koehler, 2006). PCK includes ways of representing and formulating a subject that makes it understandable to others (Shulman & Bernard, 1986). Students' backgrounds, prejudices, misunderstandings, factors that make learning certain content easy or difficult, and several other factors emerge as important dynamics of PCK based on the discussion given. PCK will be interpreted briefly as knowledge to facilitate student learning through teacher interpretation and transformation of subject matters in contextual conditions and levels provided by students (Angeli & Valanides, 2009; Koh, et. al., 2010). TCK is the knowledge used to design and use technology in changing certain contents, representing various forms of content, and enriching content with technology. TCK is about selecting and using technology to communicate the specific content of a subject (Harris & Holer 2009). Teachers by this definition need to know not only about the content but also the strategies through which subject matters can be hung with the application of technology (Koehler et al., 2007; Mishra & Koehler, 2006; Özgün-koca., 2009; Koh, et. al., 2010). TPK is knowledge of improving pedagogical practices, components (i.e., teaching, assessment, motivation, etc.) with the application of technology into teaching and learning activities (Habibi et al., 2021, 2022; Mukminin et al., 2020, 2022). Within this knowledge base, teachers must find ways to enrich or support their teaching using certain technologies (Graham et al., 2009; Harris & Hofer, 2011; Koh et al., 2010; Mishra & Koehler, 2006).

The TPACK represents the use of technology to support content-specific pedagogical strategies (Graham et al., 2009). Although TPACK is defined as a knowledge base developed from the principles of the three main knowledge bases (C, P, T), it still transcends the other three components and has a unique structure and principles. TPACK is the intersection of teacher knowledge about curriculum content, general pedagogy, and technology (Harris & Hofer, 2011). It is knowledge of using technology to implement teaching methods for different types of subject matter (Koh et al., 2010). Based on this knowledge base, teachers need to understand the ways and strategies needed to combine content, pedagogical knowledge/experience, and technology to represent certain subject matters in various forms to facilitate learning, to make content more understandable, and make the content structure easier to understand, observable or explicit to students from various backgrounds. Each teacher in this view can apply different ways of using technology in teaching due to various contextual factors from one context to another. This study aimed to determine the valid items in the perception of TPACK competencies of physics, math, biology, and chemistry teacher candidates in one public university in Indonesia.

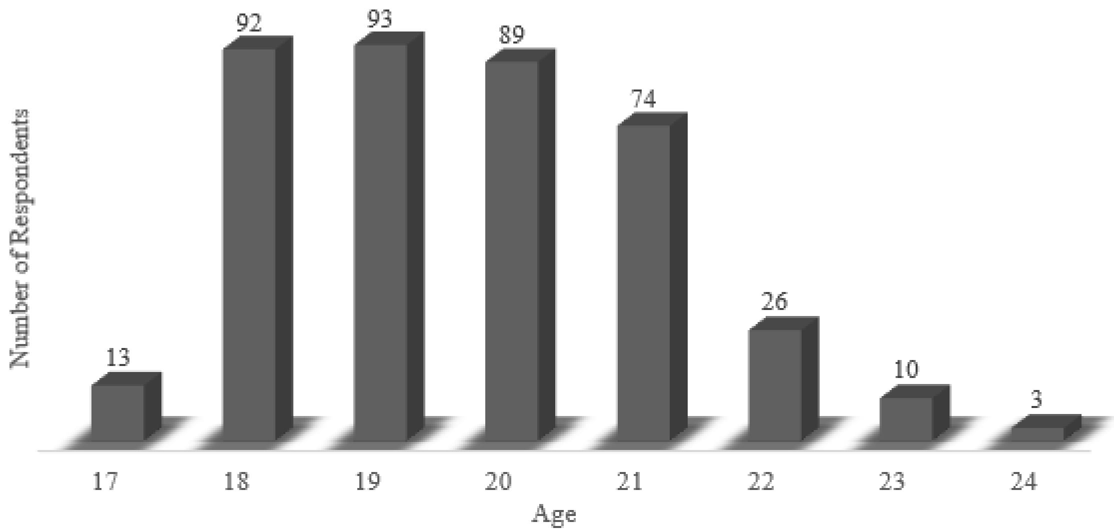
METHODOLOGY

This study used a cross-sectional survey where data were collected once from one sample at a time (Creswell, 2007). The study was conducted in four teacher education programs in one public university. This study used a stratified proportioned random sampling technique. The sample for this study consisted of 400 students from 4 teacher education programs, including Physics Education, Chemistry Education, Biology Education, and Mathematics programs.

Characteristics of Respondents

Our respondents consist of 79% (316 respondents) are females while the remaining 21% (84 respondents) are males and the age of our respondents ranged from 17 to 24 years old as presented in Figure 1.

FIGURE 1
RESPONDENTS AND AGE



Data Collection and Analysis

The questionnaire consisted of two sections. Section 1 requested demographic information (year, age, and gender) of the physics, math, biology, and chemistry teacher candidates while section 2 listed 75 items that we developed from the literature review as we discussed in the conceptual framework including 8 items for TK indicators, 17 items for CK indicators, 10 items for PK indicators, 8 items for PCK indicators, 8 items for TCK indicators, 15 items for TPK indicators, and 9 items for TPACK indicators. We distributed the questionnaire through Google Forms.

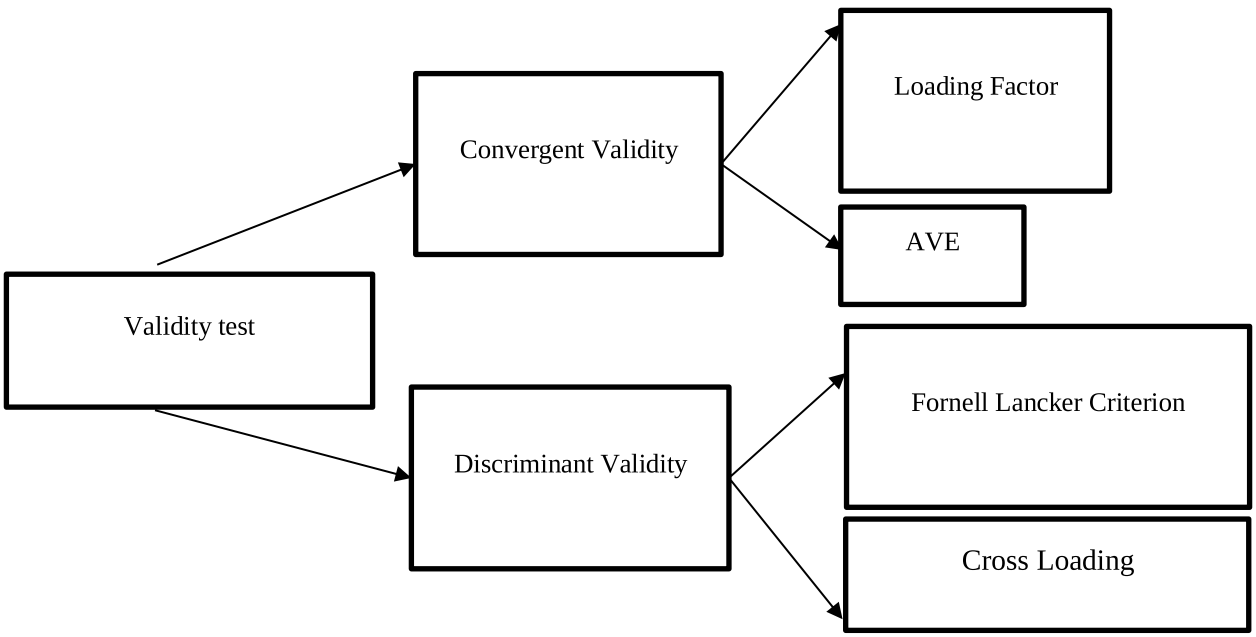
We utilized *Likertscale* by using a range of scores from 1 to 5. The questionnaire was distributed from January 2021 to March 2021 to physics, math, biology, and chemistry teacher candidates. A total of 400 completed questionnaires were received. The sample consisted of 100 physics teacher candidates, 100 math teacher candidates, 100 biology teacher candidates, and 100 chemistry teacher candidates and the age of sample ranged from 17-24 years old. The Cronbach's alpha for the seven TPACK variables is presented in table 1 below.

TABLE 1
CRONBACH ALPHA VALUE OF THE TPACK INSTRUMENT

	Cronbach's Alpha
Content Knowledge	0,779
Pedagogy Content Knowledge	0,792
Pedagogy Knowledge	0,948
TPACK	0,822
Technology Content Knowledge	0,829
Technology Knowledge	0,771
Technology Pedagogy Knowledge	0,767

The value of Cronbach's alpha for all variables was above 0.70 (Fornell & Lancker, 1981). It can be concluded that all of the TPACK variables were reliable. To analyze the 400 completed questionnaires, we used the Structural Equation Model-Partial Least Square (SEM-PLS) due to the fact that SEM-PLS is a robust multivariate analysis method despite minimal requirements for sample size and data validity (Hair et al., 2011). In this study, we used SmartPLS 3.0 software. To look at the validity through SmartPLS3.0, we conducted several steps as presented in Figure 2.

FIGURE 2
STAGES OF VALİDİTY TEST

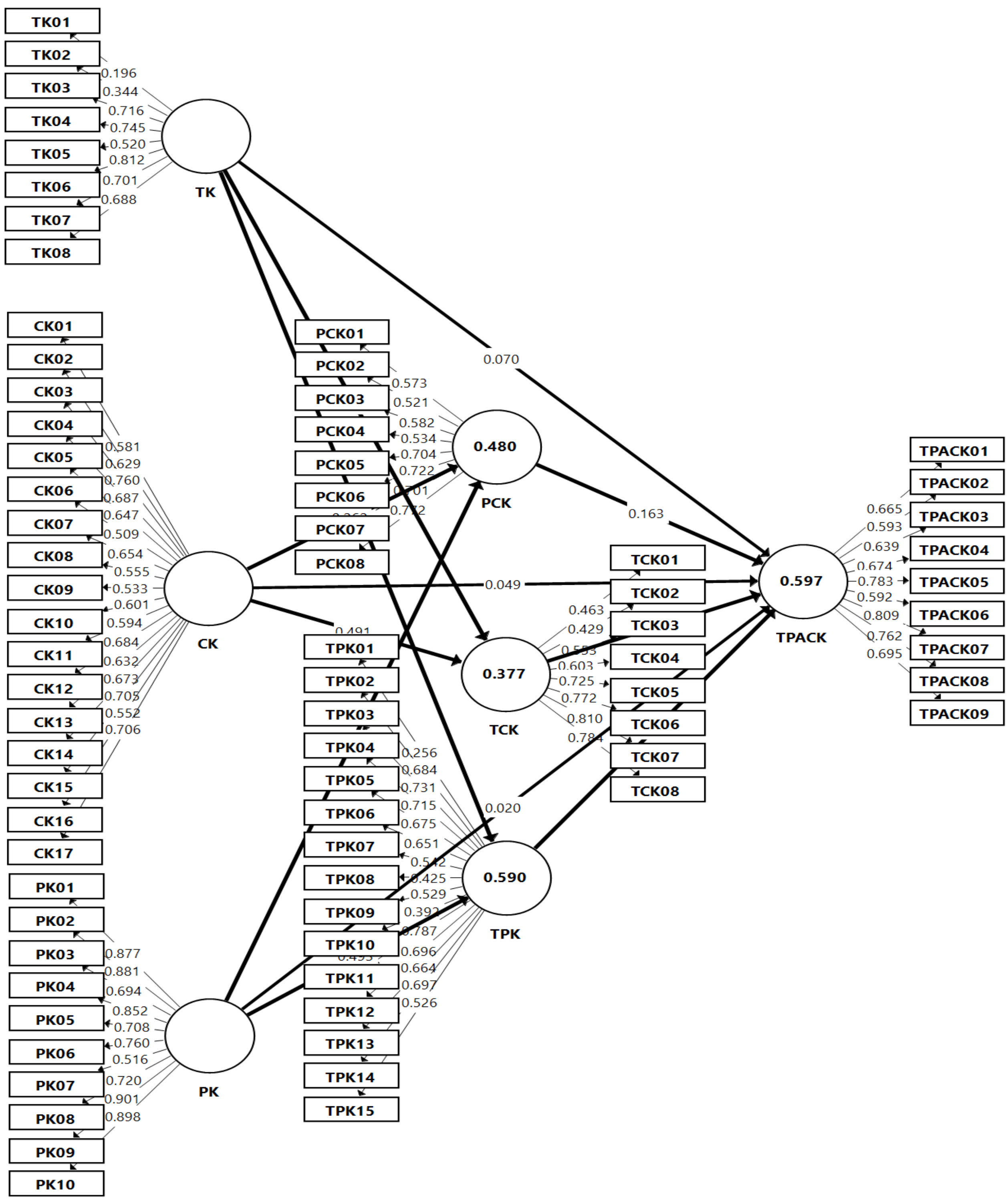


RESULTS AND DISCUSSION

Convergent Validity

The results of the analysis for the values of loading factor and the average variance extracted (AVE) for the recommended loading factor values were FO > 0,7 and AVE> 0,5 (Hair, Hult, Ringle, & Sarstedt, 2013) as presented in the following.

FIGURE 3
LOADING FACTOR VALUE OF TPACK İNSTRUMENT



In assessing the measurement model for the loading factor values, several items have values below 0.70 as presented in the following tables. For the Content Knowledge (CK) variable, 17 statement items were validated and based on the results of SmartPLS analysis; it was obtained that there were 14 statements with loading factor values below 0.07. As a result, there were only 3 valid items, namely CK03, CK15, and CK17 as presented in Table 2.

TABLE 2
VALUE OF LOADING FACTOR FOR CK VARIABLES

Types of Competency Variables	Items	Value of LF
Content Knowledge	CK01	0,581
	CK02	0,629
	CK04	0,687
	CK05	0,647
	CK06	0,509
	CK07	0,654
	CK08	0,555
	CK09	0,533
	CK10	0,601
	CK11	0,594
	CK12	0,684
	CK13	0,632
	CK14	0,673
	CK16	0,552

For the Technology Knowledge (TK) variables, of 8 items, there were 4 items with a value below 0.07. Thus there were 4 valid items, namely TK03, TK04, TK06, and TK07 as presented in Table 3.

TABLE 3
VALUE OF TK VARIABLES

Types of Competency Variables	Items	Value of LF
Technology Knowledge	TK01	0,196
	TK02	0,344
	TK05	0,520
	TK08	0,688

For the Pedagogy Knowledge (PK) variables, there were 2 items with a loading factor value below 0.70. Thus, there were 6 valid items, namely PK01, PK02, PK04, PK05, PK06, and PK08 as depicted in Table 4.

TABLE 4
VALUE OF PK VARIABLES

Types of Competency Variables	Items	Value of LF
Pedagogy Knowledge	PK03	0,694
	PK07	0,516

For the PCK variables, 4 items had loading factor values below 0.07 and the valid items were PCK05, PCK06, PCK07, and PCK08 as presented in Table 5.

TABLE 5
VALUE OF PCK VARIABLES

Types of Competency Variables	Items	Value of LF
Pedagogy Content Knowledge	PCK01	0,573
	PCK02	0,521
	PCK03	0,582
	PCK04	0,534

For the TCK variables, there were 5 items, namely TCK01, TCK02, TCK03, and TCK04 which had a loading factor value below 0.070, thus, there were four invalid items as presented in Table 6.

TABLE 6
VALUE OF TCK VARIABLES

Types of Competency Variables	Items	Value of LF
Technology Content Knowledge	TCK01	0,463
	TCK02	0,429
	TCK03	0,553
	TCK04	0,603

For the TPK variables, there were 12 statements with a value below 0.07. Thus, there were only 3 valid items, namely TPK03, TPK04, and TPK11 as presented in Table 7.

TABLE 7
VALUE OF TPK VARIABLES

Types of Competency Variables	Items	Value of LF
Technology Pedagogy Knowledge	TPK01	0,256
	TPK02	0,684
	TPK05	0,675
	TPK06	0,651
	TPK07	0,542
	TPK08	0,425
	TPK09	0,529
	TPK10	0,392
	TPK12	0,696
	TPK13	0,664
	TPK14	0,697
	TPK15	0,526

For the TPACK variables, of 9 items, there were 6 items with a value below 0.07 and there were 3 valid items, namely TPACK05, TPACK07, and TPACK08.

TABLE 8
VALUE OF TPACK VARIABLES

Types of Competency Variables	Items	Value of LF
Technology Pedagogy and Content Knowledge	TPACK01	0,665
	TPACK02	0,593
	TPACK03	0,639
	TPACK04	0,674
	TPACK06	0,592
	TPACK09	0,695

After we analysed FO, then the next step was to analyse the value of AVE. Hair et al. (2013) state that the instrument is considered invalid if AVE-value> 0, 50. In table 9 below, all the variables of the TPACK competency values were above 0.50. It can be concluded that all variables are valid. It can use the AVE (Average Variance Extracted) for each latent construct or variable to evaluate the discriminant validity. The model has better discriminant validity if the square root of the AVE (Average Variance Extracted) for each construct is greater than the correlation between the two constructs in the model.

TABLE 9
THE AVERAGE VARIANCE EXTRACTED (AVE) VALUES OF TPACK VARIABLE

	Average Variance Extracted (AVE)
Content Knowledge	0,694
Pedagogy Content Knowledge	0,615
Pedagogy Knowledge	0,799
TPACK	0,738
Technology Content Knowledge	0,661
Technology Knowledge	0,592
Technology Pedagogy Knowledge	0,683

Discriminant Validity

Discriminant validity is carried out to ensure that each concept of each latent model is different from other variables. The Fornell-Lancker criterion is the next approach to assess the discriminant validity. It compares the AVE value's square root with the latent variables' correlation. Particularly, the square root of each AVE construct must be greater than the highest correlation with other constructs. Table 10 describes that the Fornell-Lancker values for the CK-CK correlation is higher than the PCK-CK, PK-CK, TPACK-CK, TCK-CK, TK- CK, and TPK-CK correlations. Also, the values of *Fornell-Lancker for the correlations of PCK*-PCK, PK-PK, TPACK-TPACK, TCK-TCK, TK-TK, and TPK-TPK are greater than other variables. It can be concluded that the variables of TPACK instrument is valid.

TABLE 10
THE FORNELL-LANCKER VALUE OF TPACK VARIABLES

	CK	PCK	PK	TPACK	TCK	TK	TPK
CK	0,833						
PCK	0,499	0,784					
PK	0,531	0,537	0,894				
TPACK	0,521	0,468	0,502	0,859			

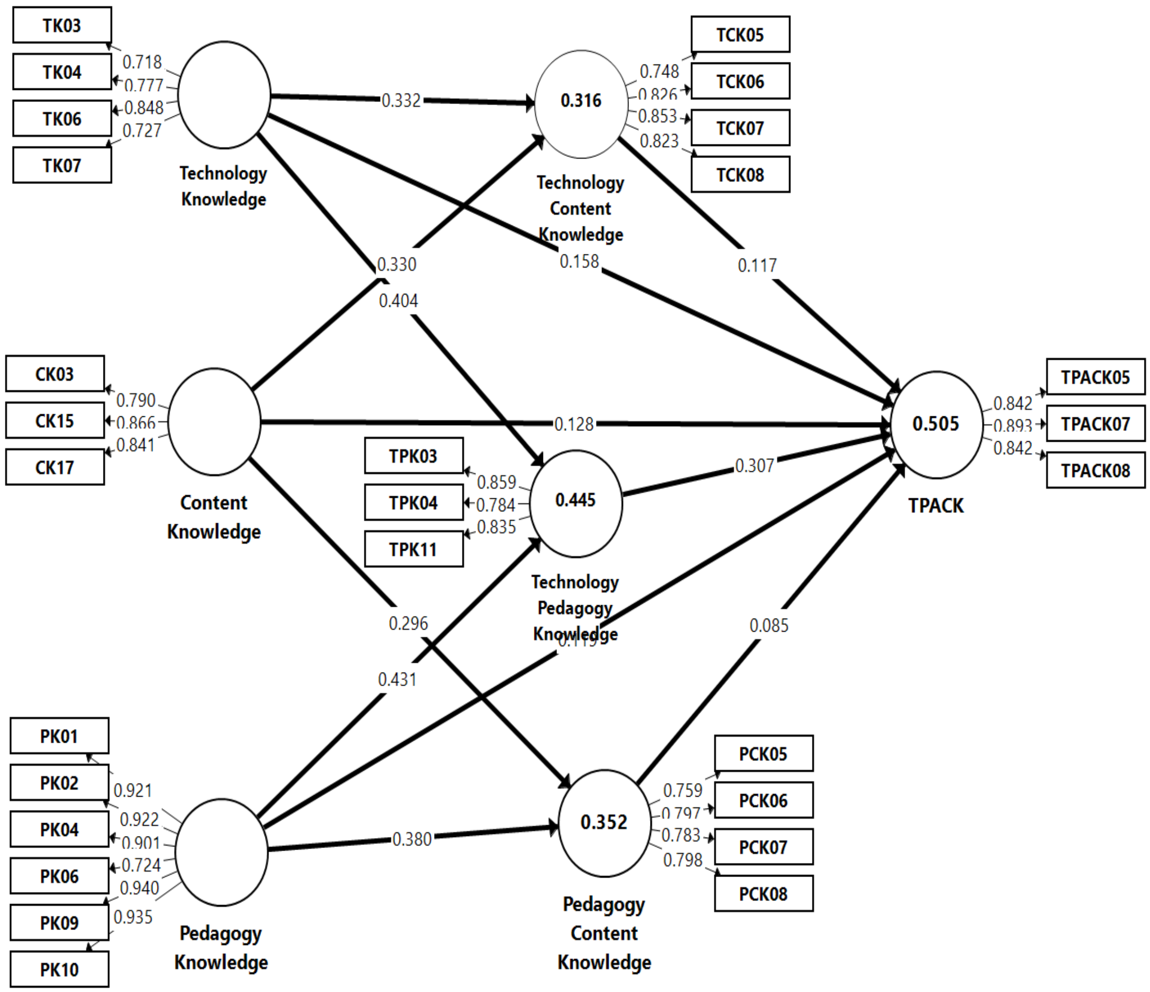
TCK	0,477	0,463	0,503	0,551	0,813		
TK	0,442	0,329	0,276	0,492	0,478	0,770	
TPK	0,528	0,486	0,542	0,639	0,644	0,523	0,827

Table 11 indicates the estimated results of the cross-loading. The cross-loading value of each item revealed the construct of the cross-loading value. It can be concluded that the items whose cross-loading values are smaller than the other values are said to be invalid.

TABLE 11
CROSS LOADING VALUE OF TPACK INSTRUMENT

	CK	**PCK**	**PK**	**TPACK**	**TCK**	**TK**	**TPK**
CK03	0,790	0,406	0,352	0,381	0,405	0,411	0,433
CK15	0,866	0,385	0,417	0,416	0,391	0,387	0,441
CK17	0,841	0,450	0,544	0,497	0,396	0,313	0,444
PCK05	0,357	0,759	0,425	0,359	0,405	0,294	0,368
PCK06	0,343	0,796	0,414	0,298	0,193	0,166	0,260
PCK07	0,460	0,787	0,376	0,471	0,457	0,345	0,542
PCK08	0,389	0,795	0,474	0,320	0,371	0,207	0,321
PK01	0,478	0,470	0,921	0,406	0,455	0,234	0,463
PK02	0,478	0,455	0,922	0,452	0,450	0,221	0,486
PK04	0,468	0,474	0,901	0,379	0,466	0,236	0,479
PK06	0,454	0,447	0,724	0,469	0,422	0,310	0,435
PK09	0,496	0,513	0,940	0,490	0,463	0,225	0,517
PK10	0,467	0,508	0,935	0,483	0,440	0,254	0,516
TCK05	0,325	0,368	0,370	0,357	0,747	0,351	0,351
TCK06	0,367	0,333	0,365	0,486	0,827	0,422	0,603
TCK07	0,344	0,284	0,417	0,407	0,853	0,382	0,553
TCK08	0,491	0,501	0,476	0,514	0,822	0,395	0,557
TK03	0,277	0,173	0,093	0,263	0,302	0,718	0,327
TK04	0,403	0,252	0,243	0,482	0,318	0,777	0,463
TK06	0,364	0,339	0,293	0,427	0,459	0,848	0,450
TK07	0,297	0,220	0,181	0,301	0,380	0,728	0,344
TPACK05	0,469	0,426	0,445	0,841	0,477	0,365	0,558
TPACK07	0,482	0,401	0,458	0,893	0,482	0,447	0,538
TPACK08	0,391	0,379	0,389	0,844	0,460	0,457	0,552
TPK03	0,429	0,410	0,424	0,615	0,549	0,458	0,861
TPK04	0,507	0,392	0,494	0,450	0,529	0,431	0,781
TPK11	0,376	0,403	0,432	0,510	0,519	0,406	0,835

FIGURE 4
TPACK INSTRUMENT



CONCLUSIONS

This study examined the valid items in the perception of TPACK competencies of physics, math, biology, and chemistry teacher candidates in one public university in Indonesia. The validation process was carefully carried out with various procedures. In the process, the theoretical principles of TPACK were taken as the main guideline. As Graham (2011) discussed, it is important to define the main concepts and relationships among the components of TPACK. The results obtained from the factor analysis and the Smart PLS procedures showed that the construction of items in the instrument and their relevance to each other is appropriate. Based on the overall results, one of the main findings of this study is that the predictive power of the core knowledge base and the second-level knowledge base on TPACK development is significantly different. Mishra and Koehler (2006) state that the second level of knowledge base does not arise only from merging two core knowledge bases. Instead, they are different knowledge bases and have their characteristic knowledge bases. Based on the analysis by using Smart PLS as shown in the figure 3, valid items are in the form of statements of 27 items consisting of a) four TK indicators; b) three CK indicators, c) six PK indicators, d) four PCK indicators, e) four TCK indicators, f) three TPK indicators, and g) three TPACK indicators.

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