The Effects of TPACK Instrument Variables on Teacher Candidates in Higher Education

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Being able to use ICT by physics, math, biology and chemistry teacher candidates is important in the Covid-19 pandemic situation. The purpose of the study was to examine the effects of Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and Technological Pedagogical Content Knowledge (TPACK) instrument variables on physics, math, biology, and chemistry teacher candidates. This study used a questionnaire consisting of 75 items to collect the data from 400 respondents. The data were analysed by using the Structural Equation Model-Partial Least Square (SEM-PLS). The findings indicated that there were positive relationships among the variables of the TPACK. Of the 18 variables that had been analysed, 12 variables had direct relationships with other variables, and 6 variables had no direct relationships. Of the 12 variables, there were 10 variables that had positive relationships and significant effects.

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

INTRODUCTION

The quality of education in schools is frequently measured by four aspects including the quality of teaching, the level of teaching, awards, and the sufficient time allocation. The quality of teaching reflects the ability of a teacher to plan and implement the teaching and learning process in the classroom (Slavin, 1991). Additionally, the pedagogical knowledge of teachers is the decisive importance for quality teaching in the classroom while good facilities can also improve the quality of teaching in order to attract the attention of students and diversify classroom activities (Zalli et al., 2020). Furthermore, in the era of technology, teachers should use technology to facilitate interactive learning inside and outside classroom (Haron et al., 2021), particularly in relation to the term of TPACK that has been around for a long time. TPCK is related to contents, theory, and technology (Mishra & Koehler, 2006).

Initially, Shulman (1986) promoted the framework of PCK focusing on developing good teaching and components that are needed. Shulman (1986) compared between teaching contents with general pedagogical principles (approaches) and teaching with content-specific pedagogical approaches. Based on the principles of PCK, TPACK was introduced as the theoretical framework that illustrates the integration of technology for effective teaching and learning activities (Mishra & Koehler, 2006; Baran et al., 2014).

Looking at the importance of TPACK and being able to use ICT by physics, math, biology and chemistry education teacher candidates in the Covid-19 pandemic situation. We conducted a study to examine the effects of Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and Technological Pedagogical Content Knowledge (TPACK) instrument variables on physics, math, biology, and chemistry teacher candidates in one public university in Indonesia.

This study was particularly to examine (1) the effect of content knowledge (CK) on technological pedagogical content knowledge (TPACK) of physics, math, biology, and chemistry teacher candidates, (2) the effect of Content Knowledge (CK) on Pedagogical Content Knowledge (PCK) of physics, math, biology, and chemistry teacher candidates, (3) the effect of Content Knowledge (CK) on Technological Content Knowledge (TCK) of physics, math, biology, and chemistry teacher candidates, (4) the effect of Pedagogical Knowledge (PK) on Technological Pedagogical Content Knowledge (TPACK) of physics, math, biology, and chemistry teacher candidates, (5) the effect of Pedagogical Knowledge (PK) on Pedagogical Content Knowledge (PCK) of physics, math, biology, and chemistry teacher candidates, (6), the effect of Pedagogical Knowledge (PK) on Technological Pedagogical Knowledge (TPK) of physics, math, biology, and chemistry teacher candidates, (7) the effect of Technological Knowledge (TK) on Technological Pedagogical Content Knowledge (TPACK) of physics, math, biology, and chemistry teacher candidates, (8), the effect of Technological Knowledge (TK) on the Technological Content Knowledge (TCK) of physics, math, biology, and chemistry teacher candidates, (9) the effect of Technological Knowledge (TK) on Technological Pedagogical Knowledge (TPK) of physics, math, biology, and chemistry teacher candidates, (10) the effect of Technological Pedagogical Knowledge (TPK) on Technological Pedagogical Content Knowledge (TPACK) of physics, math, biology, and chemistry teacher candidates, (11) the effect of Pedagogical Content Knowledge (PCK) on Technological Pedagogical Content Knowledge (TPACK) of physics, math, biology, and chemistry teacher candidates, (12) the effect of Technological Content Knowledge (TCK) on Technological Pedagogical Content Knowledge (TPACK) of physics, math, biology, and chemistry teacher candidates, (13) the effect of Content Knowledge (CK) through Pedagogical Content Knowledge (PCK) on Technological Pedagogical Content Knowledge (TPACK) of physics, math, biology, and chemistry teacher candidates, (14) the effect of Pedagogical Knowledge (PK) through Pedagogical Content Knowledge (PCK) on Technological Pedagogical Content Knowledge (TPACK) of physics, math, biology, and chemistry teacher candidates, (15) the effect of Content Knowledge (CK) through Technological Content Knowledge (PCK) on Technological Pedagogical Content Knowledge (TPACK) of physics, math, biology, and chemistry teacher candidates, (16) the effect of Technological Knowledge (TK) through Technological Content Knowledge (TCK) on Technological Pedagogical Content Knowledge (TPACK) of physics, math, biology, and chemistry teacher candidates, (17) the effect of Pedagogical Knowledge (PK) through Technological Pedagogical Knowledge (TPK) on Technological Pedagogical Content Knowledge (TPACK) of physics, math, biology, and chemistry teacher candidates, and (18) the effect of Technological Knowledge (PK) through Technological Pedagogical Knowledge (TPK) on Technological Pedagogical Content Knowledge (TPACK) of physics, math, biology, and chemistry teacher candidates.

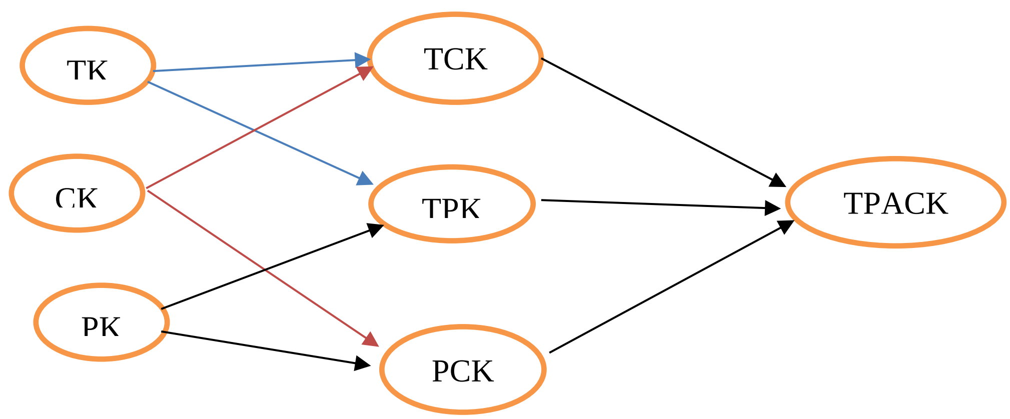
METHOD

For our study, we used total sampling or entire sampling so all of physics, math, biology, and chemistry teacher candidates at the research site were selected. A sample of year 2, 3, and 4 physics, math, biology, and chemistry teacher candidates who were enrolled at physics, math, biology, and chemistry teacher education programs at one public university in Jambi, Sumatra, Indonesia was studied. These programs prepare teachers for primary and secondary schools. To gather the data, initially, we distributed an invitation letter to teacher candidates and if they agreed, we gave them an informed consent form stating their willingness to take part in this study.

Second, after having their informed consent form, we distributed a questionnaire which was designed with 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.

To analyse 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). By using SmartPLS 3.0 software, we analysed the measurement model (outer model), structural model analysis (inner model), and hypothesis testing. In our study, we presented a SEM model which is based on the principles of the TPACK theory (Agyei & Voogt, 2012; Koh et al., 2010; Graham, 2011; Koehler et al., 2007).

FIGURE 1
THE INITIAL TPACK STRUCTURAL EQUATION MODEL (PAMUK ET AL., 2015)



FINDINGS

The Assessment of the Measurement Model

According to Hair, Hult, Ringle, and Sarstedt (2013), in evaluating the measurement model, the values of the factor loading, composite reliability (CR), and average extracted variance (AVE) are often assessed for internal consistency, and convergent validity of the model. The suggested values of factor loading are > 0.5, CR> 0.7 and ST> 0.5. Based on the results of the analysis smart PLS on the measurement models of the 75 items, it was obtained 27 valid items with the values of factor loading: > 0.5, CR> 0.7, and ST> 0.5 as that presented in Table 1

TABLE 1
THE MEASUREMENT MODEL OF CONVERGENT VALIDITY

No	Items	Loadings	CR	AVE
Content Knowledge			0,871	0,694
1	CK03	0,383		
2	CK15	0,384		
3	CK17	0,434		
Technology Knowledge			0,886	0,661
4	TK03	0,255		
5	TK04	0,362		
6	TK06	0,381		
7	TK07	0,292		
Pedagogical Knowledge			0,959	0,799
8	PK01	0,178		
9	PK02	0,185		
10	PK04	0,177		
11	PK06	0,179		
12	PK09	0,202		
13	PK10	0,200		
Technology Pedagogical Knowledge			0,866	0,683
14	TPK03	0,436		
15	TPK04	0,386		
16	TPK11	0,387		
Pedagogical Content Knowledge			0,865	0,615
17	PCK05	0,312		
18	PCK06	0,286		
19	PCK07	0,358		
20	PCK08	0,319		
Technology Content Knowledge			0,894	0,738
21	TCK05	0,259		
22	TCK06	0,326		
23	TCK07	0,287		
24	TCK08	0,355		
Technology Pedagogical Content Knowledge			0,853	0,592
25	TPACK05	0,389		
26	TPACK07	0,396		
27	TPACK08	0,379		

Table 1 shows that the results of the measurement model exceed the recommended value. It indicates that the convergent validity was satisfactory. We, then, looked at the discriminant validity. In determining the discriminant validity, we used the ratio of heterotrait-monotrait (HTMT).

TABLE 2
THE HTMT CRITERION OF DISCRIMINANT VALIDITY

	CK	PCK	PK	TPACK	TCK	TK	TPK
CK							
PCK	0,626						
PK	0,613	0,621					
TPACK	0,647	0,572	0,567				
TCK	0,585	0,552	0,566	0,657			
TK	0,566	0,401	0,309	0,601	0,591		
TPK	0,684	0,610	0,638	0,801	0,796	0,668	

To establish the discriminant validity, previous studies have suggested two different threshold limit criteria of HTMT, namely 0.85 and 0.90 (Fornell & Larcker, 1981). Based on the data in table 2, all HTMT criteria results are below the critical value of 0.85.

Assessment of the Structural Model

Structural model aims to evaluate the relationships among the hypothesized latent constructions. The structural model in PLS was evaluated by using the coefficient of determination or R-Square for endogenous constructs, path value, or coefficient t-value for each path for the interconstructed significance test on the structural model. To measure the hypothetical relationships, path estimates and t-statistics were calculated by using the bootstrap procedure of 5000. The results of the SmartPLS analysis of the bootstrap procedure are shown in Figure 2.

FIGURE 2
MODEL 1- RESULTS OF SMARTPLS ANALYSIS OF BOOTSTRAP TECHNIQUE FOR THE TPACK INSTRUMENT

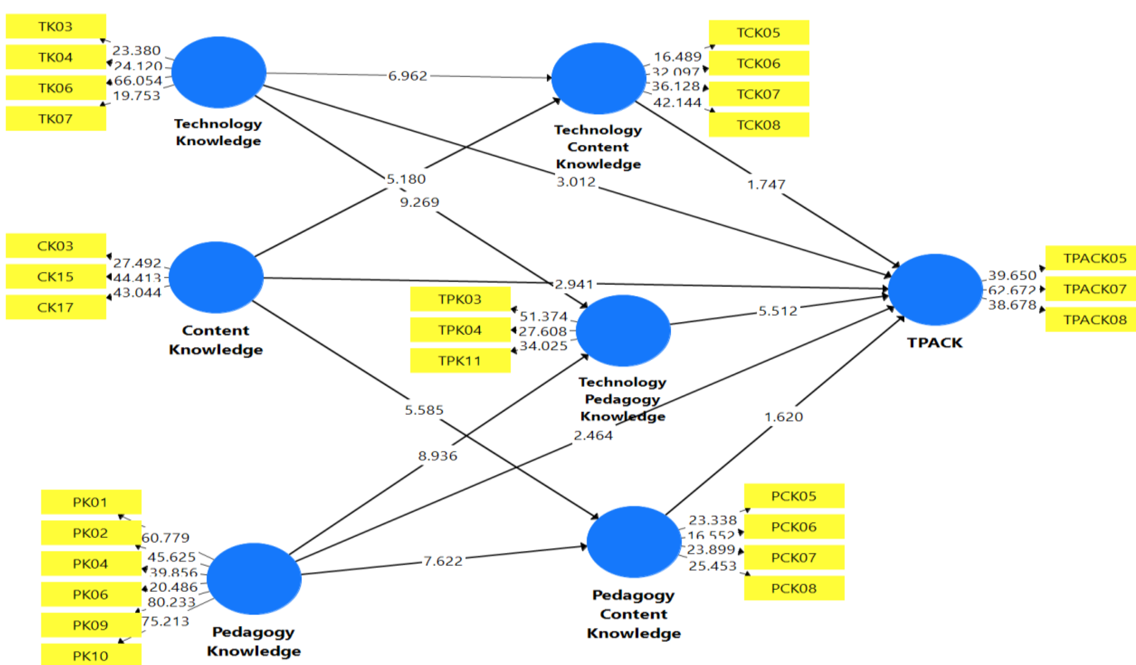


TABLE 3
VALUE OF R-SQUARE

	R Square
Pedagogy Content Knowledge (PCK)	0,352
TPACK	0,505
Technology Content Knowledge (TCK)	0,316
Technology Pedagogy Knowledge (TPK)	0,445

Table 3 shows the information about the value of R -Square for s PCK, TPACK, TCK, and TPK variable. Based on the value of R-Square, it was obtained that the value of R-square for PCK constructs was 0.352. It indicates that 35, 2 % of the variants for PCK constructs can be explained by the constructs of PK and CK while the other 64.8 % were explained by other variables of the model. The TPACK constructs have a value of R-square of 0, 505. It indicates that 50.5 % of the variants of the TPACK constructs can be explained by the constructs of TK, CK, PK, TCK, TPK, and PCK and 49, 5 % were explained by other variables outside the model. The TCK constructs have a value of R-square of 0, 316 indicating 31.6 %, of the variants for TCK constructs can be explained by the constructs of TK and CK and 68.4 % were explained by other variables outside the model. The TPK constructs have a R-square value of 0.445. It means that 44.5% of the variants for the TPK constructs can be explained by the TK and PK constructs while the other 55.5% of variants were explained by other variables outside the model. For the significance level of the path coefficient value, it was obtained by using the bootstrap procedure. It produced the t-statistical value that was compared with the t-table value. The results of the path coefficients and their values can be seen in table 3.

TABLE 4
THE HYPOTHESIS TESTING RESULTS

No	Variable	O	STDEV	t-Stat	P_{Values}	t-tabel (α = 0,05)	Decision
1	CK -> TPACK	0,128	0,044	2,941	0,128	1,966	Accepted
2	CK -> PCK	0,296	0,053	5,585	0,296	1,966	Accepted
3	CK -> TCK	0,330	0,064	5,180	0,330	1,966	Accepted
4	PK -> TPACK	0,119	0,048	2,464	0,119	1,966	Accepted
5	PK -> PCK	0,380	0,050	7,622	0,380	1,966	Accepted
6	PK -> TPK	0,431	0,048	8,936	0,431	1,966	Accepted
7	TK -> TPACK	0,158	0,053	3,012	0,158	1,966	Accepted
8	TK -> TCK	0,332	0,048	6,962	0,332	1,966	Accepted
9	TK -> TPK	0,404	0,044	9,269	0,404	1,966	Accepted
10	TPK -> TPACK	0,307	0,056	5,512	0,307	1,966	Accepted
11	PCK -> TPACK	0,085	0,052	1,620	0,085	1,966	Rejected
12	TCK -> TPACK	0,117	0,067	1,747	0,117	1,966	Rejected

The data in table 4 indicate that the hypothesis is accepted or rejected by looking at the value of t-statistics and t-table. Of 12 hypotheses that were proposed in this study, two hypotheses of the relationships among variables of PCK -> TPACK and TCK -> TPACK were rejected by looking at the t- statistic value is lower than the t-table value.

TABLE 5
THE HYPOTHESIS TESTING RESULTS OF PATH INTERVENING VARIABLES

	T Statistics	P_{Values}	Ttest (α = 0,05)	Decision
CK -> PCK -> TPACK	1,487	0,138	1,966	Rejected
PK -> PCK -> TPACK	1,595	0,111	1,966	Rejected
CK -> TCK -> TPACK	1,431	0,153	1,966	Rejected
TK -> TCK -> TPACK	1,867	0,062	1,966	Rejected
PK -> TPK -> TPACK	4,658	0,000	1,966	Accepted
TK -> TPK -> TPACK	4,681	0,000	1,966	Accepted

For the intervening variables, based on the SmartPLS analysis in table 5, it can be seen that there were four intervening variables with their rejected hypotheses by looking at the values of t- statistics were much lower than the values of the t-table. Those variables were CK -> PCK -> TPACK, PK -> PCK -> TPACK, CK -> TCK -> TPACK, TK -> TCK -> TPACK.

DISCUSSION

Based on the SmartPLS analysis, it indicates that factors that affect TPACK instrument variables in this study. The model -figure 2- shows that there are variables that have a positive influence on each other and some have no effects. Model 1 shows the direct effects of variables on the TPACK instrument (table 4). The partial value of the generated variable Content Knowledge (CK) pitch toward Technological Pedagogical Content Knowledge (TPACK) shows the relationship positive with a value of β = 0.044; t = 2. 941; p = 0.003, then t-statistic variables CK affect significantly to variable TPACK. The findings of this study indicated that the variables of content knowledge (CK) and the pedagogical content knowledge (PCK) show a positive relationship with a value of β = 0.053; t = 5. 585; p = 0.296. Moreover, the effect of content knowledge (CK) on technological content knowledge (TCK) indicated a positive relationship with the value of = 0.064; t = 5180; p = 0.330. Also, in this study, we found that the effect of pedagogical knowledge (PK) on the technological pedagogical content knowledge (TPACK) showed a positive relationship with a value of β = 0048; t = 2,464; p = 0.119. The effect of pedagogical knowledge (PK) on the pedagogical content knowledge (PCK) showed a positive relationship with a value of β = 0.050; t = 7,622; p = 0.380.

Next, the effect of pedagogical knowledge (PK) on the technological pedagogical knowledge (TPK) showed the positive relationship with a value of β = 0048; t = 8.936; p = 0.431. In our study, it is interesting that we found that the effect of technological knowledge (TK) on the technological pedagogical content knowledge (TPACK) showed a positive relationship with a value of β = 0.053; t = 3.012; p = 0.158. We found that the effect of technological knowledge (TK) on technological Content Knowledge (TCK) shows the relationship positive with a value of β = 0.048; t = 6.962; p = 0. 332. Moreover, our findings revealed that the effect of Technological Knowledge (TK) on technological Pedagogical Knowledge (TPK) showed a positive relationship with a value of β = 0:044; t = 9.269; p = 0. 404. We also found that the effect of Technological Pedagogical Knowledge (TPK) on technological Pedagogical Content Knowledge (TPACK) showed a positive relationship with a value of β = 0.056; t = 5.512; p = 0.307 while the N value of = 0.052; t = 1,620; p = 0.085 showed that the effect of Pedagogical Content Knowledge (PCK) on the Technological Pedagogical Content Knowledge (TPACK) was positive. For the effect of Technological Content Knowledge (TCK) on Technological Pedagogical Content Knowledge (TPACK), it revealed the value of = 0.067; t = 1.747; p = 0.117. It can be concluded that TCK and TPACK variables had a positive relationship and had no significant effect as seen from the t value which is smaller than the t table value of 1,966.

CONCLUSION

It is concluded that there is a significant positive relationship among the variables on the TPACK instrument. There were 18 relationship variables that had been analysed, 12 variables had a direct relationship with other variables, and 6 variables had an indirect relationship. In the 12 direct variables, there were 10 variables that had a positive relationship and had a significant effect, namely the relationships among variables of 1) CK -> TPACK; 2) CK -> PCK; 3) CK -> TCK; 4) PK -> TPACK; 5) PK -> PCK; 6) PK -> TPK; 7) TK -> TPACK; 8) TK -> TCK; 9) TK -> TPK; 10) TPK -> TPACK. Additionally, there were 2 variables that had a positive relationship but had no significant effect, namely the PCK -> TPACK and TCK -> TPACK variables.

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