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ANALYSIS OF TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK) ABILITY BASED ON SCIENCE LITERACY FOR PRE-SERVICE PRIMARY SCHOOL TEACHERS IN LEARNING SCIENCE CONCEPTS

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ABSTRACT

This study intends to describe and investigate the ability profile of Technological Pedagogy Content Knowledge (TPACK) based on scientific literacy for pre-service primary school teachers. The measurement of student TPACK skills is needed to determine the knowledge of technology that will be implemented in the learning process. Students' TPACK knowledge needs to be developed because integration between pedagogical abilities, material content, and technology is needed. This research is quantitative survey research. This study tested a TPACK model, which was described by the relationship between latent variables, namely from seven components, including TK, PK, CK, TPK, TCK, PCK, and TPACK. The data collection technique used a questionnaire instrument with 46 items. The questionnaire instrument was filled out by 206 pre-service primary school teachers who had taken the Science Concept, Science Application, Science Teaching Learning Course, and Field Experience Practice Courses. The results were then calculated and analyzed using a modeling test with a Structural Equation Modeling (SEM) approach. The results showed that PCK variability could be influenced by the CK and PK components of 51.5%. While the variability of TCK can be influenced by the components of CK and TK of 42.7%. The variability of the TPK can be influenced by the PK and TK components of 45.2%. Finally, the magnitude of the effect of PK, CK, TK, PCK, TPK, and TCK components on TPACK is 61.0%. The TPACK profile of pre-service primary school teachers is good with the factors that contribute most to the components that go into PK and CK. As a result, the findings of this study will contribute to the development of a more thorough profile of the TPACK competencies of pre-service primary school teachers, which can enhance their capacity to incorporate technology when they become teachers in the future.

Keywords: science concepts; science literacy; TPACK

INTRODUCTION

Entering the era of revolution 4.0, significant changes occurred from various lines. Major changes are taking place in information, communication, and technology. To be part of education 4.0, teachers must become proficient in technology. According to Minister of National Education Regulation No. 16 of 2007, teachers must master information and communication technology in order to advance their own development and promote student learning. This statement is strengthened by Permendikbud No. 22 of 2016 in the standard process, namely, the learning principle used is that teachers must be able to utilize information and communication technology to increase the efficiency and effectiveness of learning (Sintawati & Indriani, 2019). The demands of this accelerating change need to be accompanied by appropriate and relevant educational

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practices. The impact of the COVID-19 pandemic on the education line has influenced the massive use of information technology. Institutions of Educators and Education Personnel (LPTK) as a printer for prospective teachers has improved as an adaptation to this change. Students are required to master 21st-century skills, including 1) core subject and 21st-century themes, 2) learning and innovative skills, 3) information, media, and technology skills, and 4) life and career skills (Heflebower, 2012). In addition to these skills, students must have science literacy skills (Fakhriyah et al., 2018). Science literacy is a person's ability to analyze and use the science of daily life.

In reality, the science literacy of Indonesian students is in the bottom 10. One of the causes of this low achievement was teachers' lack of competence in delivering learning in the field of science. This is a particular concern for the Primary Educational Teacher Department Universitas Muria Kudus study program as a printer for pre-service teachers to improve student competence in order to have 21st-century skills and be able to create innovative learning so that primary school students have qualified science literacy skills (Fakhriyah et al., 2019), can innovate, have learning skills, can use and utilize emerging information technology (Papp et al., 2014; Deviana & Aini, 2022). For this reason, professional teachers must be prepared when they are still students or pre-service teachers. A pre-service teacher must be able to plan and incorporate appropriate teaching strategies for students with diverse backgrounds and learning styles (NSTA, 2003). In addition, the use of technology in teaching activities is needed to synergize with the demands of the 21st-century (Desstya, 2018). In today's digital age, incorporating technology into the learning process is crucial. In addition to having an understanding of pedagogy and content components, educators also need to be able to combine these two components with technology (Agustini et al., 2019).

Primary Educational Teacher Department Universitas Muria Kudus students have been equipped with various compulsory courses to develop pedagogical and professional competencies. A good teacher must be able to master the content (lesson material/subject material) and master the science of teaching (pedagogy) (Purwianingsih et al., 2010). Shulman (1987) revealed that professional teachers are not only those who have pedagogic and content skills but also integrate the two. The problem is that if the teacher only has pedagogic knowledge, the teacher will use various learning models or methods without delving into the concept of the material. The result is that the student's knowledge is not deep. Vice versa, if the teacher only has content knowledge, it will be difficult to transfer it to students, even though it is the teacher's task. Furthermore, with the development of the current digital era, a teacher can use technology in learning to make it easier to convey abstract material to be easily understood by students (Maeng et al., 2013). Technology development is a means to make it easier for a person to do a job. Mishra & Koehler (2006) revealed that competence in using technology is an important part and component that supports effective learning. The field of teacher education is undergoing transition and staying current with technological innovations is no longer sufficient. Students and teachers must be able to search for the correct knowledge at the right time for the right purpose using a variety of learning technology. Concerning an introduction to the TPACK framework for science education, 88% of students reported feeling more confident in their ability to understand scientific concepts, and 94% of students reported feeling more knowledgeable and confident about using scientific Web resources (Sheffield et al., 2015). So that a framework for the ability of Technological Pedagogical Content Knowledge (TPACK) is formed, which comes from three core components, namely technology (TK), pedagogic (PK), and content knowledge (CK). The three components then produce four integration components formed from this slice of core competencies which include Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), and Technological Pedagogical content knowledge (TPACK) (Mishra & Koehler, 2006; Maeng et al., 2013; Utami & Guntara, 2021).

TPACK is also known as Pedagogical Content Knowledge (PCK). PCK is defined as specific knowledge in which there is knowledge of how to teach the material. TPACK is the relationship between technological knowledge, pedagogy, and content that must be mastered by teachers (Suryawati et al., 2014). The TPACK component refers to the teacher's ability to plan and incorporate the use of technology into the core tasks associated with the subject and its topics in order to support student learning as well as how to represent the learning material with technology using pedagogical means (Cox & Graham, 2009; So & Kim, 2009; Mishra et al., 2011; Herring et al., 2016). Sahin et al. (2013) reveal that TPACK knowledge is described as a form of multi-integration and transformation.

The concept of TPACK can be seen in Figure 1, which shows that TPACK is built from content knowledge, pedagogical knowledge, and technological knowledge (Chai et al., 2013).

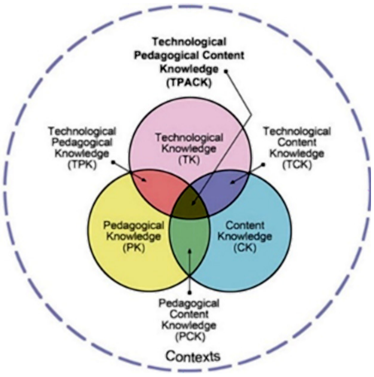

Figure 1. TPACK Concept

The results of the preliminary study on monitoring and evaluation activities in the Field Experience Practice Course in the Primary Educational Teacher Department Universitas Muria Kudus found that students have not been able to make learning tools that follow the mandate of the 2013 curriculum, namely strengthening literacy and 4C-based learning (collaboration, communicative, creative, critic) as well as the implementation of online learning and blended learning during this pandemic. Furthermore, students were given a project to design learning for primary school students and showed that class management skills were still lacking. This is because students cannot design learning that follows the demands of the field properly. Even though learning planning is a process of making decisions as a result of reasoning about specific learning goals and objectives (Setyawanto, 2012; Fabian et al., 2019)

Partially the TPACK approach affected science literacy. Science literacy can be seen as the indicator of the TPACK approach for the TPACK aspects of the scientific process because the questions that represent indicators of aspects of the scientific process can be answered by most students (Irmita & Atun, 2018). To determine whether professional development initiatives based on TPACK have improved teachers' TPACK, the researchers have been creating a variety of TPACK instruments. It became more crucial for researchers to record their subjects' levels of understanding in TPACK (Koehler et al., 2012).

In connection with the importance of measuring the readiness of pre-service teachers' TPACK abilities, it is necessary to carry out initial measurements to determine students' abilities. After getting a portrait of TPACK, the results are used to develop devices and instruments to improve students' TPACK. This is done so that the development of TPACK products follows the characteristics of students so that they are right on target. This is in line with Glowtz and O'Brien (2017) explaining that the TPACK framework has been tested and developed in various educational contexts. This framework is considered a powerful tool for analyzing and reflecting on the context and process of learning and teaching. The TPACK framework was used to explore the relationship between technical skills, instructional design, and their relation to pedagogy (Fabian et al., 2019). Based on the results of a systematic literature review in the last few years, TPACK is the most discussed topic (Irwanto, 2021). However, it is rarely discussed about TPACK at the higher education level (Mourlam et al., 2021).

Students' TPACK profiles become an input for developing learning tools and learning management systems for science learning. This is following research conducted by Salas-Rueda (2020) with his research topic developing TPACK through a web application. So, this study aims to analyze and describe the profile of technological pedagogy content knowledge (TPACK) capabilities based on the science literacy of pre-service primary school teachers. Measurement of students' TPACK skills is needed to determine the technological knowledge that will be implemented in the learning process. Students' TPACK knowledge needs to be developed because integrating pedagogical abilities, material content, and technology is indispensable.

METHODS

This research is a cross-sectional survey quantitative research (Creswell, 2016). Determination of the sample selected by stratified random sampling technique. Questionnaires were distributed to odd-semester students of class 2021/2022 who have taken the Science Concepts, Science Applications, Science Teaching Learning Course, and Field Experience Practice Courses. A total of 206 students participated in this study. Experts agree that many factors affect the minimum sample size (Sukarmin & Sin, 2022). Meanwhile, Lynn (2019) revealed that stratified random sampling has the advantage that it can ensure that the final sample has been proportionally distributed with the population in terms of the required stratification. Questionnaires were distributed through a google form containing seven TPACK components, namely TK (Technology Knowledge), PK (Pedagogy Knowledge), CK (Content Knowledge), TPK (Technology Pedagogy Knowledge), TCK (Technology Content Knowledge), PCK (Pedagogy Content Knowledge), and TPACK (Technological Pedagogy and Content Knowledge).

This is because the relationship between TPACK elements each has multidiscipline capabilities that support each other if implemented in the learning process. The instrument used is a 21st-century TPACK questionnaire developed based on the results of previous research with adjustments (Koehler & Mishra, 2009; Chai et al., 2011; Puspitarini et al., 2013; Valtonen, 2017; Yulisman et al., 2019).

The data collection technique used a questionnaire with 46 items. To achieve the objectives of this study, two types of data were analyzed, namely descriptive statistics and inferential statistics. This questionnaire uses a Likert scale which then calculates the percentage index using the formula for the number of scores obtained by the sample divided by the maximum score multiplied by 100. The results of the data analysis of this calculation are then interpreted with the criteria as in Table 1 below.

Table 1. Interpretation Categories

Percentage of Respondents (%)	Interpretation
1-19,9	Very lacking
20-39,9	Less
40-59,9	Fair
60-79,9	Good
80-100	Excellent

(Sugiyono, 2013)

After calculating the percentage index, the components are directly and indirectly affected by SEM analysis through the SMART PLS program. Puspitarini et al. (2013) mention that analysis of a structural model includes a test of the significance of the estimated coefficient by specifying a significant degree. If the initial model does not match the empirical data, it is performed by modifying the model and retesting it using the same data. Ringle et al. (2015) reveal that SmartPLS 3.0 can be used to assess measurement models and test hypotheses. Convergent validity and discriminant criteria are used in making an assessment of the measurement model, while hypothesis testing is used to test hypotheses (Sukarmin & Sin, 2022).

The first step is to test the validity and reliability. The validity of the questionnaire as (latent variable) is measured through the confirmatory factor analysis (CFA) model, namely, in the measurement model, the standard loading factors of the measured variable against the latent variable (factor) is an estimate of the validity of the measured variable and conducts a reliability test of each latent variable to find out the extent of the consistency of the measuring instrument. Hair et al. (2017) suggest that CFA is part of SEM to test how a measured variable or indicator is good in describing or representing a number of a factor. The Validity Test can be seen from the loading factor, where the value must be greater ≥ 0.5. The reliability can be seen from the value of Cronbach Alpha (Rahayu, 2022).

In this case, the second step of the assumption test is a multicollinearity test that can be seen from its VIF value. Furthermore, the next step is to test the hypothesis, which is also an evaluation of the model structure. Finally, a descriptive analysis is carried out to characterize the characteristic variables so that the initial goal can be met, namely, knowing the profile of students' abilities.

RESULTS AND DISCUSSION

To measure TPACK skills, students need to know the technological knowledge that will be implemented in the learning process. The interrelationship of TPACK elements each has multidiscipline capabilities that support each other if implemented in the learning process. Students' TPACK knowledge needs to be developed because integrating pedagogical abilities, material content, and technology is indispensable. TPACK is a form of multi-integration and transformation (Sahin et al., 2013). Multiintegration, namely content, pedagogy, and technology, is necessary for students as a provision in presenting material, teaching to students, and providing a meaningful learning experience for students (Holland & Piper, 2016).

The questionnaire was distributed through a google form containing seven TPACK components, namely TK (Technology Knowledge), PK (Pedagogy Knowledge), CK (Content Knowledge), TPK (Technology Pedagogy Knowledge), TCK (Technology Content Knowledge), PCK (Pedagogy Content Knowledge), and TPACK (Technology Pedagogy and Content Knowledge). The questionnaire contains 46 items and is distributed to students in the first semester of the class of 2021/2022 who have taken courses in Science Concepts and Science Applications in Primary Educational Teacher Department Universitas Muria Kudus. The results of filling out the questionnaire by 206 students of pre-service primary school teachers can be described with the percentage index value presented in Figure 2.

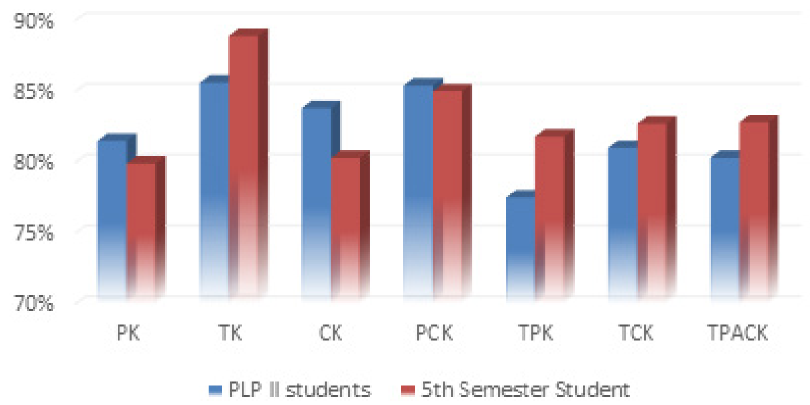

Figure 2. TPACK Capability Profile of Field Experience Practice Courses Students and 5th Semester Students

Based on Figure 2, it can be seen that all components are in a good category, with kindergarten and PCK getting higher scores compared to other components in both semesters five students and Field Experience Practice Courses students. Meanwhile, the TPK component in Field Experience Practice Courses students is the lowest component compared to other components. In 5th-semester students, the PK component is the lowest component in percentage score. This shows that students taking Field Experience Practice Courses (semester 7) have difficulty integrating technology with the pedagogical component. Meanwhile, in semester five, students struggle with teaching or pedagogical abilities. The results of descriptive statistical analysis can be seen in Table 2.

Table 2. Descriptive Statistics and Normality Criteria

Construct	Item Code	Item	Descriptive Statistics				Normality Criteria	
			Min	Max	Mean	Standard Deviation	Excess Kurtosis	Skewness
PK	PK1	1	1	4	3.233	0.534	0.851	-0.055
	PK2	2	2	4	3.175	0.491	0.417	0.365
	PK3	3	2	4	3.422	0.559	-0.874	-0.279
	PK4	4	2	4	3.345	0.560	-0.721	-0.116
	PK5	5	2	4	3.102	0.561	0.094	0.026
	PK6	6	1	4	3.121	0.607	0.743	-0.328
	PK7	7	1	4	3.223	0.565	0.546	-0.172
	PK8	8	1	4	3.102	0.619	0.074	-0.193
	PK9	9	2	4	3.350	0.570	-0.703	-0.182
TK	TK1	10	2	4	3.602	0.499	-1.426	-0.537
	TK2	11	2	4	3.549	0.553	-0.558	-0.714
	TK3	12	1	4	3.447	0.595	0.299	-0.698
	TK4	13	1	4	3.350	0.570	0.261	-0.341
CK	CK1	14	1	4	3.223	0.556	0.639	-0.142

Construct	Item Code	Item	Descriptive Statistics				Normality Criteria	
			Min	Max	Mean	Standard Deviation	Excess Kurtosis	Skewness
	CK2	15	2	4	3.189	0.598	-0.392	-0.096
	CK3	16	2	4	3.403	0.564	-0.816	-0.265
	CK4	17	2	4	3.335	0.521	-0.885	0.176
PCK	PCK1	18	1	4	3.447	0.544	0.247	-0.425
	PCK2	19	1	4	3.320	0.525	0.523	-0.048
	PCK3	20	1	4	3.034	0.671	0.173	-0.331
	PCK4	21	2	4	3.495	0.528	-1.275	-0.279
	PCK5	22	2	4	3.456	0.545	-1.034	-0.279
	PCK6	23	2	4	3.510	0.510	-1.716	-0.150
	PCK7	24	2	4	3.398	0.509	-1.437	0.196
	PCK8	25	2	4	3.403	0.529	-1.159	-0.002
	PCK9	26	1	4	3.248	0.617	1.267	-0.590
	PCK10	27	2	4	3.636	0.501	-0.811	-0.801
	PCK11	28	1	4	3.563	0.586	2.126	-1.270
TPK	TPK1	29	1	4	3.199	0.611	0.715	-0.397
	TPK2	30	1	4	3.296	0.595	0.927	-0.491
	TPK3	31	1	4	3.112	0.698	1.206	-0.760
	TPK4	32	1	4	3.155	0.611	0.135	-0.228
	TPK5	33	1	4	3.194	0.592	0.306	-0.226
	TPK6	34	1	4	3.121	0.566	1.450	-0.307
TCK	TCK1	35	1	4	3.330	0.564	1.291	-0.445
	TCK2	36	2	4	3.277	0.628	-0.650	-0.292
	TCK3	37	2	4	3.291	0.542	-0.546	0.062
	TCK4	38	2	4	3.199	0.561	-0.196	0.018
	TCK5	39	2	4	3.252	0.570	-0.421	-0.052
TPACK	TPACK1	40	2	4	3.311	0.567	-0.605	-0.102
	TPACK2	41	1	4	3.257	0.546	0.639	-0.116
	TPACK3	42	1	4	3.223	0.565	0.546	-0.172
	TPACK4	43	1	4	3.238	0.537	0.804	-0.067
	TPACK5	44	2	4	3.248	0.514	-0.273	0.270
	TPACK6	45	1	4	3.277	0.545	0.576	-0.126
	TPACK7	46	1	4	3.257	0.563	0.478	-0.190

Table 2 shows that all skewness statistics for the TPACK dimension are between -1.270 and 0.365. Meanwhile, the kurtosis statistic is between -1,716 and 1,450, respectively. If the skewness threshold value is -2 skewness 2 and the kurtosis threshold is -7 kurtosis 7, then the data is close to normally distributed (Curran et al., 1996). Based on the skewness and kurtosis data, the distribution of the data in this study is classified as normal with the Initial PLS-Path Model in Figure 3.

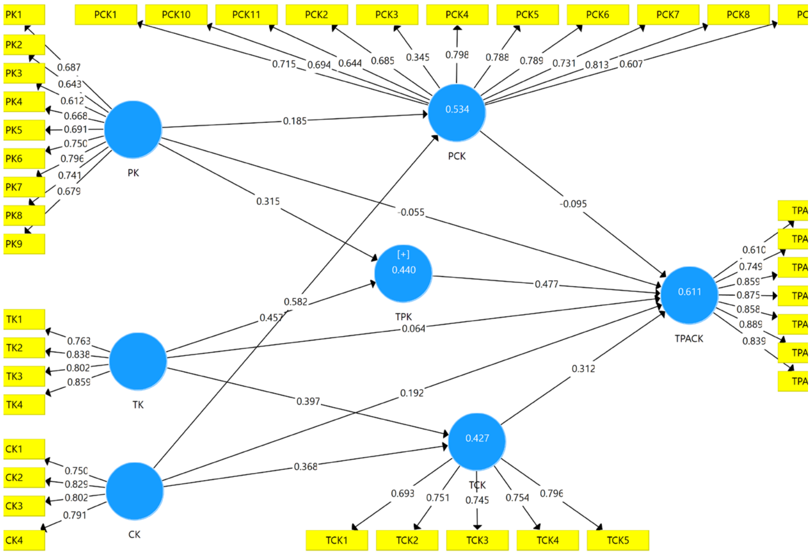

Figure 3. Initial PLS-Path Model

The next step is to look at construct reliability and validity. This step tests the validity of the measurement model. This study uses indicators of loading, composite reliability (CR), and extracted average variance (AVE). For indicator loading, the threshold value is 0.708 or higher, the composite reliability (CR) is 0.70 or higher, and the extracted mean-variance (AVE) must be 0.50 or higher (Hair et al., 2014). The HTMT criteria are used to assess discriminant validity because, according to Henseler et al. (2015), the HTMT criteria are more sensitive to detecting discriminant validity and the cross-loading criteria in Table 3 below.

Table 3. Convergent Validity

Construct	Item	Outer Loading	Cronbach's Alpha	CR	AVE
CK	CK1	0.749	0.804	0.872	0.629
	CK2	0.829			
	CK3	0.802			
	CK4	0.791			
PCK	PCK1	0.713	0.902	0.919	0.535
	PCK10	0.706			
	PCK11	0.653			
	PCK2	0.687			
	PCK4	0.793			
	PCK5	0.789			
	PCK6	0.798			
	PCK7	0.734			
	PCK8	0.810			
	PCK9	0.603			
PK	PK1	0.703	0.862	0.892	0.510
	PK2	0.658			

Construct	Item	Outer Loading	Cronbach's Alpha	CR	AVE
	PK4	0.658			
	PK5	0.693			
	PK6	0.769			
	PK7	0.795			
	PK8	0.749			
	PK9	0.676			
TCK	TCK1	0.693	0.803	0.864	0.560
	TCK2	0.751			
	TCK3	0.745			
	TCK4	0.754			
	TCK5	0.796			
TK	TK1	0.763	0.833	0.888	0.666
	TK2	0.838			
	TK3	0.802			
	TK4	0.859			
TPACK	TPACK1	0.610	0.914	0.933	0.667
	TPACK2	0.749			
	TPACK3	0.859			
	TPACK4	0.875			
	TPACK5	0.858			
	TPACK6	0.889			
	TPACK7	0.839			
TPK	TPK1	0.763	0.907	0.929	0.685
	TPK2	0.786			
	TPK3	0.815			
	TPK4	0.876			
	TPK5	0.869			
	TPK6	0.850			

Based on Table 3, CK (4 items), PCK (11 items), PK (9 items), TCK (5 items), TK (4 items), TPK (6 items), TPACK (7 items) ranged from 0.721 to 1000, while the Average Variance Extracted (AVE) for this dimension is between 0.585 and 1000, so the results are modified by removing PCK3 and PK3 items so that the AVE is obtained > 0.5 all, and the other items are retained. Therefore, all dimensions and all items can be considered to meet the convergent validity criteria. The distribution of this student ability profile instrument was analyzed using Confirmatory Factor Analysis (CFA), resulting in all the criteria needed, both convergent and discriminant validity, had been met. To test the structural model of the TPACK profile of students in semester seven and semester five, standard beta (β) values and t-values can be used through a bootstrap procedure with a re-sample of 5,000 (Hair et al., 2017). This CFA analysis has the advantage of combining test item analysis and construct analysis so that the results are more valid (Prudon, 2015).

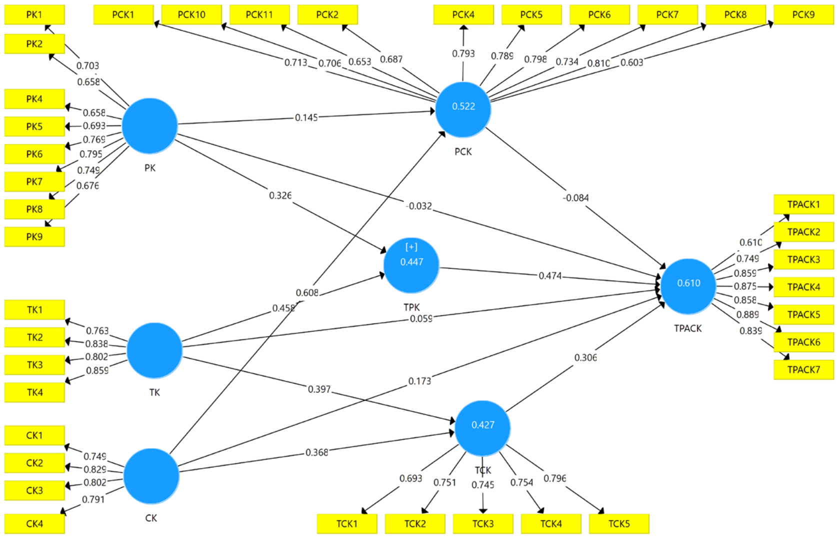

Figure 4. Modified PLS-Path Model

The evaluation of the model in PLS includes two stages: the evaluation of the measurement model and the evaluation of the structural model (Yulisman et al., 2020). Evaluation of the measurement model consists of convergent and discriminant validity and reliability. Convergent validity is seen from the loading factor and average value extract (AVE). Figure 4 depicts the model structure used after removing the PCK3 and PK3 items.

Table 4. Discriminant Validity: Heterotrait Monotrait Ratio Statistics (HTMT)

	CK	PCK	PK	TCK	TK	TPACK	TPK
CK							
PCK	0.828						
PK	0.881	0.661					
TCK	0.679	0.757	0.677				
TK	0.556	0.680	0.512	0.684			
TPACK	0.587	0.573	0.539	0.792	0.605		
TPK	0.527	0.626	0.581	0.778	0.685	0.795	

Note: $HTMT_{0.85}$
Remarks:
- There are HTMTs that take the criteria of < 0.85

The hypothesis in this study was tested with the Smart PLS 3.0 software developed by Ringle et al. (2015). To find out whether these components have a significant effect or not by looking at the path coefficients as shown in Table 5 below.

Table 5. Hypothesis Testing Summary

Hypothesis	Path	Std. Beta	Std. Error	t-value	Bias	2.50%	97.50%	Decision
H1	CK -> PCK	0.657	0.085	7.690	0.000	0.471	0.811	Supported
H2	CK -> TCK	0.368	0.058	6.368	0.001	0.252	0.476	Supported
H3	CK -> TPACK	0.177	0.066	2.692	-0.006	0.058	0.319	Supported
H4	PCK -> TPACK	-0.087	0.087	0.996	0.020	-0.268	0.065	Unsupported

Hy-poth-esis	Path	Std. Beta	Std. Error	t-value	Bias	2.50%	97.50%	Decision
H5	PK -> PCK	0.082	0.095	0.854	0.007	-0.100	0.275	Unsupported
H6	PK -> TPACK	-0.038	0.099	0.381	-0.013	-0.227	0.157	Unsuported
H7	PK -> TPK	0.331	0.065	5.063	0.003	0.198	0.454	Supported
H8	TCK -> TPACK	0.306	0.115	2.663	0.022	0.103	0.532	Supported
H9	TK -> TCK	0.397	0.061	6.522	0.003	0.269	0.509	Supported
H10	TK -> TPACK	0.059	0.075	0.794	-0.008	-0.076	0.217	Unsupported
H11	TK -> TPK	0.459	0.054	8.477	-0.001	0.350	0.562	Supported
H12	TPK -> TPACK	0.476	0.106	4.500	-0.021	0.269	0.657	Supported

Note: p≥ 0.05 ; -> t-value decision> 1.96 (2-tailed)

From the information in Table 5 above, there is a significant correlation between the main components of TPACK, except for components PCK, PK, and TK did not have a significant effect. The components that directly affect TPACK are CK, TCK, TK, and TPK. TK and PK do not have a direct effect but need mediating variables, namely TCK and PCK. This follows the opinion of Celik et al. (2014), which shows that pre-service teachers with more knowledge of technology will have more knowledge of pedagogy and content. Further analysis to determine the effect size of the correlation above can be seen from the F square value presented in Table 6.

Table 6. *F Square*

	CK	PCK	PK	TCK	TK	TPACK	TPK
CK		0.429		0.187		0.027	
PCK						0.007	
PK		0.007				0.002	0.163
TCK						0.102	
TK				0.218		0.005	0.313
TPACK							
TPK						0.261	

Information:
CK has a great contribution to PCK
CK has a medium contribution to TCK
CK has a weak contribution to TPACK
PCK has a weak contribution to TPACK
PK has a weak contribution to PCK
TCK has a medium contribution to TPACK
TK has a medium contribution to TCK
TK has a weak contribution to TPACK
TPK has a medium contribution to TPACK

Table 7 shows that the PCK variability can be influenced by the CK and PK components of 51.5%. While the components of CK and TK can influence the variability of TCK by 42.7%. The variability of the TPK can be influenced by the PK and TK components by 45.2%. Finally, the magnitude of the effect of PK, CK, TK, PCK, TPK, and TCK components on TPACK is 61.0%. This study shows that a seven-factor survey adapted to measure the TPACK of pre-service teachers has sufficient construct validity to test hypotheses as to the results of the CFA analysis with high reliability (Rukmana & Handayani, 2020). CFA is used to test the suitability of the measured variables (Ghazali & Nordin, 2019). The results of the data analysis show that all competencies of CK, PCK, PK, TCK, TK, and TPK have an effect on TPACK, but some have a moderate effect, and some have a low effect. CK has the largest contribution to PCK competence, CK contributes weakly to TPACK, PCK contributes weakly to TPACK, TCK contributes moderately to TPACK, TK contributes weakly to TPACK, and TPK contributes moderately to TPACK. This is following the research of Absari et al. (2020), which found that TK and PK had a positive effect on TPK, and TPK had a positive effect on TPACK.

Table 7. R Square

Construct	R Square	Category	Meaning
PCK	0.515	Moderate	51% are determined by those who enter PK and CK, and there are 49% are other factors outside the model.
TCK	0.427	Weak	
TPACK	0.610	Moderate	
TPK	0.452	Weak	

CK is related to knowledge of the material being taught. The profile of pre-service students shows good results because learning delivery is carried out well if students master the material. This is in line with the research of Fariyani et al. (2020) that the ability to determine concepts in the material being taught is the biggest factor in improving pedagogical knowledge skills (PCK).

CK, TPK, and TCK competencies contributed moderately to TPACK. In learning, teachers use ICT to involve learning, including the use of media, attendance, and assessment, so that constructivist-oriented learning, technological knowledge, and pedagogical knowledge can be realized (Gao et al., 2011). These competencies are related to knowledge of technology following certain materials and mastery of technology and materials adapted to learning management so that meaningful learning is practical and fun for students. Students as pre-service teachers must master it because they face students of the Alpha generation. Children born after 2010 are used to technology, so teachers must master technology to suit their characteristics (Spasova, 2022). In addition, the Primary Educational Teacher Department Universitas Muria Kudus has presented courses that include technology mastery skills in learning. The COVID-19 pandemic requires teachers and students to master technology. This pandemic has an impact on increasing the use of technology and e-learning in learning (Tawafak et al., 2021). Learning for Generation Z and Alpha must use appropriate media and technology.

This discovery enriches TPACK research by strengthening the validity of previously created instruments (Valtonen et al., 2017) for use in two learning environments: offline and online classrooms. After this analysis, the research team found the TPACK profile of pre-service primary school teachers (Valtonen et al., 2017; Rukmana & Handayani, 2020) with the factor that contributed the most, namely 51% determined by those who entered PK and CK; there were 49% other factors outside the TPACK model. Content knowledge (CK) contributes the most to teacher TPACK (Maknun, 2014).

The PCK component is in the moderate category, so it can be said that the pedagogical knowledge is following the content. The results of Sojanah et al. (2021) research show that PCK has the greatest effect on TPACK. The PCK component is in the moderate category, so it can be said that pedagogical knowledge is following the content. This is similar to the opinion of Mishra & Koehler (2006) that a teaching approach that fits the content and knows the elements of the content can be organized for better teaching.

The TPACK component is also in the moderate category, meaning that students can apply their TPACK quite well. This supports Tanak's (2020) research which states that pedagogical abilities have more impact on the development of TPACK, while high kindergarten abilities do not have enough impact on TPACK abilities. This is different from the results of research conducted by Yulisman et al. (2019), where the components of CK, PK, and PCK have a direct and indirect effect on teacher TPACK. However, Chai et al. (2011) mentioned that the seven components of TPACK had a positive and significant relationship. Therefore, the results of this analysis can be used as the first step in developing students' TPACK capabilities. Following Rahayu's opinion (2022), increasing TPACK capabilities cannot be done partially or individually, only by increasing knowledge or technological ability or content knowledge, or pedagogical knowledge but must be carried out in an integrated manner. This TPACK is at the heart of teaching, which describes the type of knowledge teachers need to integrate effective technology into learning (Zhang & Tang, 2021).

CONCLUSION

The TPACK ability of Primary Educational Teacher Department Universitas Muria Kudus students is in a good category. After this analysis, the research team found the TPACK profile of pre-service primary school teachers with the factor that contributed the most, namely 51% determined by those who entered PK and CK; there were 49% other factors outside the TPACK model. These findings are then used as material to develop learning tools and LMS to promote the growth of the TPACK of PGSD students as pre-service teachers in terms of scientific literacy competence. The findings of this study will contribute to the development of a more thorough profile of pre-service primary school teachers' TPACK competencies, which in turn can improve their ability to integrate technology when becoming a teacher in the future. Students' TPACK profiles are input for developing learning tools and learning management systems for science learning.

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