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The effect of technological pedagogy knowledge and technological content knowledge on TPACK of primary prospective teachers

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Abstract Technological Pedagogy Content Knowledge (TPACK) is a skill that 21st-century teachers must possess. This study measured the influence of the Technological Pedagogical Knowledge (TPK) and Technological Content Knowledge (TCK) toward the TPACK of 150 primary prospective teachers at Universitas Muria Kudus on the innovation courses in science learning. The quantitative survey research applied some instruments, such as test instruments, project observation sheets, and performance. The researchers analyzed the data with a multiple regression. Based on data analysis, the results show that the multiple regression model of Y = 1.752 + 0.452X1 + 0.524X2. TPK and TCK have an effect of 98.3% on student TPACK with 45.2% of TPK ability influencing TPACK ability and 52.4% of TCK ability influencing TPACK ability. Based on these results, the researchers concluded that TCK significantly and highly influenced TPK. The results recommend lecturers to better prepare the students with TCK than TPK abilities.

Keywords: teacher skills, primary school, teacher candidates, science learning

1. Introduction

Many factors, including teachers, influence an excellent education system. The teacher is essential in determining learning success because the teacher deals directly with students. The development of education is currently running dynamically to keep up with the era because children are the future of the nation. Current education must prepare children to survive the demands of the era. In this era, the developments of teacher and student experiences in learning are vital to achieve maximum output (Okoye et al., 2020). Therefore, teachers must have qualified competence based on the demands of the 21st century, such as literacy and TPACK. TPACK is an important skill for 21st-century science teachers (Anud & Caro, 2022). TPACK is a targeted learning development in the 21st century (Koh et al., 2015). On the other hand, scientific literacy is a teacher's skill in implementing science in everyday life (Sadler & Zeidler, 2009). Students may find that science is difficult to understand. This situation makes them lose writing interest. Ucak (2019) explains that students like games and experiments rather than writing. Tsekhmister (2022) found the results of his research obtained data that the use of technology in learning will encourage students to become independent learners and improve teacher learning. Therefore, teachers must devise a strategy for teaching science, including TPACK. Thus, TPACK equips teachers with the science knowledge and skils to integrate technology effectively into their teaching practices.

A literacy measurement of primary school students, based on PISA, showed low results for Indonesian students (OECD, 2022). Primary school teacher education at Universitas Muria Kudus as an educational institution for educational staff (LPTK) must prepare the primary school teacher candidates to have the relevant abilities of the 21st century. Teacher quality is related to nation-building and determines the quality of education (Jan, 2017). Learning development using TPACK positively influences teacher confidence in teaching and 21st -century learning designs (Koh 2017). Assessment and delivery of material using technology must adhere to the necessities of 21st -century students (Gopo, 2022). 21st -century teachers need teaching skills and conceptual mastery by integrating technology into learning to improve student soft skills (Kuloğlu & Karabekmez, 2022). However, not all teachers meet the TPACK competence qualifications. Teachers may experience many problems and are clueless about technology. The teachers also do not master the material optimally and cannot manage to learn properly. The results of necessity analyses in the primary school teacher education program Universitas Muria Kudus found the student teacher candidates had average TPACK and could integrate technology into learning (Fakhriyah et al., 2022). These TPACK elements are very important to master. Lecturers as teacher educators must know the TPACK-contributing components optimally. The lecturers must also diagnose student abilities and improve the TPACK components of the students by encouraging the literacy skills of the prospective teacher candidates.

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Many studies attempted to improve the TPACK ability of teachers and teacher candidates. For example, Fakhriyah et al. (2017) found 33.8% of students had a functional level. On the other hand, the remaining percentage, 66.2%, had a nominal level. Fakhriyah et al. (2022), found that CK, PK, TK, TPK, PCK, and TCK had a 61% effect on TPACK, but the magnitude of the effect of each component remained unknown. Messina & Tabone (2012) also found a correlation between new technological knowledge and the teaching of teachers toward student activities. However, further analysis, diagnosis, and evaluation of TPACK components are important to carry out for further TPACK improvement. Likewise, Susanti et al. (2022) argue the importance of determining the correlation between TPACK component variables is necessary to improve students' TPACK abilities. Önen & Sincar (2019) also encourage future research to evaluate teacher performance evaluation for improving learning. Chui & Zang (2022) also encourage future researchers to examine literacy and TAPCK. In the field of educational technology, the concepts of Technological Pedagogical Knowledge, Technological Content Knowledge, and Technological Pedagogical Content Knowledge are interconnected (Koehler, 2014). From the background, the current research measured the influence of material mastery competence (TCK) and teaching methods (TPK) toward the TPACK of teacher candidates.

2. Literature Review

TPACK, Technological Pedagogy Content Knowledge, consists of technology, pedagogy, and knowledge. These three elements create meaningful learning and are inseparable. The implementation of technology is to guide the learning with excellent teaching and knowledge of the material. Thus, the learning will be effective and meet the 21st century demands. Therefore, teachers must have high technological proficiency. Teachers' perceptions of TPACK influence teachers' perspectives on 21st-century learning (Suganda et. al, 2021). Digital learning media can develop students' skills to meet 21st-century necessities (Abdullateef, 2021). Figure 1 shows the seven components of TPACK (Koehler & Mishra, 2008).

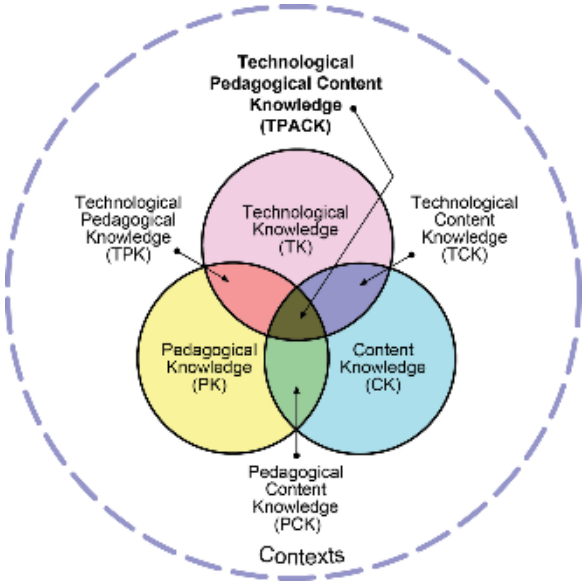

Figure 1 TPACK Framework.

The first component is Pedagogical Knowledge (PK). This component deals with knowledge mastery for the teachers in the learning process. Some skills based on this component are teaching methods, class management, lesson planning, and student activity assessment. The second component is Content Knowledge (CK). This component deals with knowledge and substance of subject matter to be mastered by teachers and to share with the students. Teacher material mastery influences the student's understanding. The third component is Technology Knowledge (TK). This component deals with knowledge of technology implementation for learning, for example, the awareness of technology as a communication process or medium to convey the teaching materials. The fourth component is Pedagogical Content Knowledge (PCK). This component focuses on the learning process, and the selected materials by the teachers to teach. Thus, this PCK deals with the teaching methods, learning strategies, learning plans, learning media, and supportive learning facilities. The fifth component is Technological Content Knowledge (TCK). This component deals with the technology in a scientific discipline as the medium to convey the materials to the students. The sixth component is Technological Pedagogical Knowledge (TPK). This component deals with the teachers' knowledge of technology and learning process associations. The seventh component is Technological Pedagogical Content Knowledge (TPACK). TPACK integrates technology mastery, pedagogy mastery, and material mastery. TPACK is a requirement in organizing learning. Teachers must apply the content pedagogical knowledge (Almonacid-Fierro, 2023). Teachers may also combine the technology implementation with various classroom methods (Young, 2016).

3. Materials and Methods

This research measured the effect of TPK (Technological Pedagogy Knowledge) and TCK (Technological Content Knowledge) on TPACK (Technological Pedagogy Content Knowledge) in the college students of the primary school teacher education program at Muria Kudus University. These students were the candidates of primary school teachers. This quantitative applied a survey research design with a correlational method (Cresswell, 2018).

3.1. Sample and Data Collection

The research population consisted of 262 students in the fifth semester of 2022/2023. The researchers selected the subjects with random sampling. The results were 150 college students in the fifth semester, the year 2022/2023. They took science learning innovation courses. The independent variables were TPK and TCK while the dependent variable was TPACK. The applied instruments were essay test questions, projects, and performance observation sheets to measure the lesson design, teaching simulations, worksheets, teaching materials, learning media, assessment instruments, lesson plans, and problem-solving tests (Hilyana et al., 2023; Fakhriyah et al., 2022). After obtaining the data, the researchers grouped the data into two competencies. The first one was TPK, consisting of lesson design, lesson plans, and teaching simulations. The second group was TCK, consisting of worksheets, teaching materials, learning media, and problem-solving tests.

2.2. Analyzing of Data

After collecting the data, the researchers analyzed the data with multiple regression tests to determine the influence of TPK and TCK toward TPACK of the prospective teacher students (Cresswell, 2018). The regression analysis was useful for calculating the correlation among variables (Kumari & Yadav, 2018). Table 1 shows the square-correlation coefficient as proposed by Hair et al. (2013).

Table 1 R Square.

No	Score	Criteria
1.	0.75	Substantial
2.	0.50	Moderate
3.	0.25	Weak

3. Finding

This research measured the influence of TPK and TCK toward TPACK of the primary school teacher candidates at Muria Kudus University. These research subjects took science learning innovation courses in semester 5. This research lasted for a semester. The course consisted of three classes with a total of 150 students. They attended the course for 16 meetings. During this semester, the lecturers shared the material of being excellent science teachers based on TPACK competence qualifications and 21st-century necessities.

After collecting the data, the researchers examined the data normality. The results found all data from TPK, TCK, and TPACK had normal distribution based on the mean scores. Then, the researchers promoted regression tests with the assistance of SPSS. This process was useful to determine the multiple linear regression equations of TPK and TCK toward TPACK. Table 2 shows the results.

Table 2 ANOVA Test.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13403.793	2	6701.896	4329.682	.000[b]
	Residual	227.541	147	1.548		
	Total	13631.333	149			

a. Dependent Variable: TPACK (Y). b. Predictors: (Constant), TCK (X2), TPK (X1)

The ANOVA table is an F-test to determine the effects of independent variables on the dependent variable. Here are the proposed hypotheses:

Ho: TPK and TCK simultaneously have no significant effect on TPACK.
Ha: TPK and TCK simultaneously have a significant effect on TPACK.

Table 2 shows the calculation results from SPSS. The obtained sig-value is 0.000 lower than 0.05. The value denies Ho. Thus, TPK and TCK simultaneously and significantly influence TPACK. The next step was – examining the data with F-test. Then, the researchers analyzed the regression to determine the value of the influence of TCK and TPK toward TPACK. Table 3 shows the r-test results.

Table 3 shows an R-value of 0.983. The value indicates that 98.3% effects in the model are from TPK and TCK. On the other hand, the test shows only 1.7% effects are from the unobserved and external factors of the model.

The ANOVA table is a t-test to determine whether the independent variable partially affects the dependent variable. The hypothesis proposed is as follows.

Ho_1: TPK has no significant effect on TPACK.
Ha_1: TPK simultaneously has a significant effect on TPACK.
Ho_2: TCK has no significant effect on TPACK.
Ha_2: TCK simultaneously has a significant effect on TPACK.

Table 3 R Square of TPACK.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.992[a]	.983	.983	1.244

a. Predictors: (Constant), TCK (X2), TPK (X1)

Table 3 shows the calculation with the assistance of SPSS. The obtained sig-value is 0.000, lower than 0.05. Thus, the result rejects Ho. Therefore, TPK and TCK significantly influence TPACK. From Table 4, the researchers formulated the multiple regression model with the formula of Y = 1.752 + 0.452X1 + 0.524X2.
From the analyses, the researchers concluded the correlation of the variables based on the R-square values. Table 5 shows the results.

Table 5 shows the ability of TPK and TCK for every student is different. Figure 1 and Figure 2 show the influence of TCK on TPACK.

Table 4 R Square of TPK and TCK.

Model		Unstandardized B	Coefficient Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	1.752	1.678		1.044	.298
	TPK (X1)	.452	.021	.244	21.481	.000
	TCK (X2)	.524	.007	.882	77.766	.000

a. Dependent Variable: TPACK (Y)

Table 5 R Square.

Components	R Square	Category
TPK	0.452	Weak
TCK	0.524	Moderate
TPK & TCK	0.983	Substantial

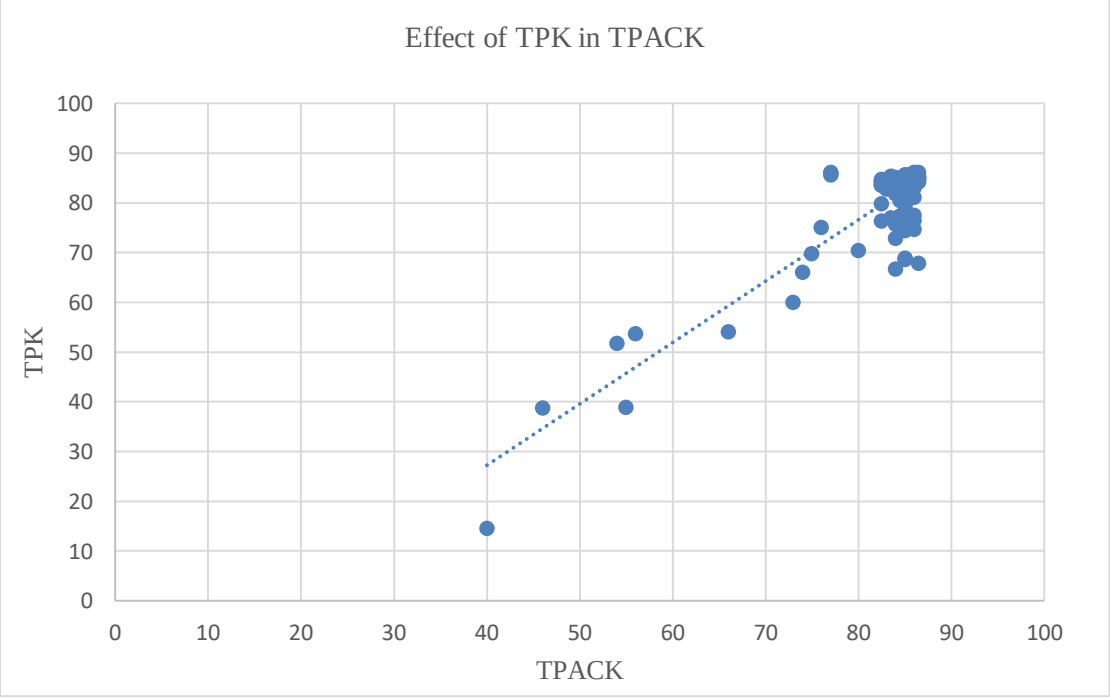

Figure 2 Effect Of TPK in TPACK.

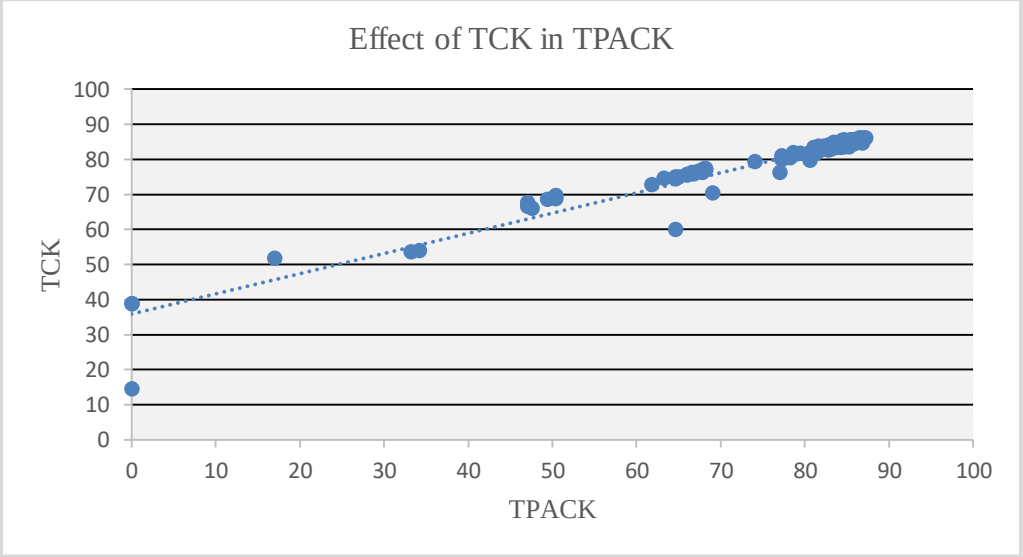

Figure 3 Effect of TPK in TPACK.

4. Discussion

Teachers must be literate to apply various devices and media for learning. This literacy must consist of the awareness of technology, design, and learning (Koehler et al., 2013). The 21st century requires technological implementation in learning (Albeta et al., 2023). The education of the current era hones the TPACK of teachers to improve the excellent soft skills of the students (Kereluik et al., 2013). In this research, the course brought TPACK by providing projects, assignments, and practices for the students. The course also encouraged the students to think analytically by analyzing national and international journal articles, lesson designs, essential competencies, and learning objectives; and to create worksheets, teaching materials, innovative media, assessments, evaluations, lesson plans, portfolios, teaching simulations, and problem-solving analysis based on science learning in primary schools. The researchers grouped these activities into TPK, TCK, and TPACK competencies. The researchers calculated the data to obtain the mean scores and analyzed the data with a linear regression test. In this post-pandemic situation, the ideal learning for Indonesian students must foster a joyful learning environment with ideal lecturers (Helaluddin et al., 2023).

Based on the SPSS analysis, Table 4 shows the regression test of TPK (X1) and TCK (X2) effects on TPACK (Y). Then, based on the effects, the researchers arranged a multiple regression model Y = 1.752 + 0.452X1 + 0.524X2. These results found high competence of TPK and TCK led to high TPACK of students. If the TPK (X) = 0 and TCK (X) = 0, then the TPACK (Y) result is 1.752. If the TPK (X) = 1 and TCK (X) = 1, then the TPACK (Y) result is 2.728. The result of this equation is positive and indicates high TPK and TCK competencies of a teacher. Therefore, the TPACK competency is also high. The result also indicates the influence of other unobserved factors on TPACK.

In this TCK component, teachers taught the materials from one study discipline across various study disciplines with the assistance of technology. On the other hand, TPK competence dealt with teacher creativity in using technology for pedagogical purposes. This situation shows the adaptive teacher skill to new learning practice demands (Koehler & Mishra, 2008). The ability to explain concepts is an essential skill for teachers and to maximize the teachers' insight and knowledge. The survey results about teacher skills found that senior teachers tended to be less confident about their pedagogical content knowledge. However, younger teachers were more confident because they could master the materials better than the senior teachers. However, senior teachers still had better pedagogical mastery than younger teachers (Koh et al., 2017).

In this research, the teacher candidates obtained excellent TPACK skills. The perception of applying technology in the classroom influenced the TPACK of the students (Joo et al., 2018). Fakhriyah et al. (2022) also found that some competencies, such as PK, CK, TK, PCK, and TPCK had an effect of 61% toward TPACK. Based on the TPACK framework, CK deals with teachers' creativity to re-think the 21st-century demands and the materials teachers teach (Koehler & Mishra, 2008).

The researchers measured the effects of TPK and TCK toward TPACK after obtaining the regression equation, the significance of the variable, and the linearity of the model. Table 2 shows the linear correlation between X to Y based on the result of F-table and F-count with significant criteria. If the TPK competency increases by one score, then the TPACK competency will increase by 0.452. Meanwhile, if the TCK competency increases by one score, the TPACK competency will increase by 0.524. The data means TPK and TCK have a positive effect on TPACK. Teacher experience, self-efficacy, training, facilities, and infrastructure positively influence teacher TPACK (Sojanah et al., 2021).

Table 4 shows that the correlation coefficient of TPK to TPACK is 0.452. The researchers checked the results in Table 1. The result found that TPK had a moderate correlation with TPACK and so did TCK. The result indicates that TPK has a 45.2%

effect on TPACK while TCK has a 52.4% effect on TPACK. On the other hand, the remaining percentage, 2.4%, comes from other unobserved factors.

The design of The Primary School Teacher Education Study program curriculum facilitates the students to be superior educational undergraduate candidates. The framework of the curriculum focuses on material mastery to prepare the teacher candidates with excellent knowledge and eligibility to teach or continue their study levels. However, the material content at that moment was higher than the pedagogical knowledge content. This matter happened because the science of pedagogy was mostly for students in teacher professional education programs. Therefore, in this research, the teacher candidates had better TCK than TPK. From the science material content, the students received lectures about science concepts, biophysics, basic science research, applied science learning, and ethnoscience. These materials are important for the students to compete in professional education for teachers and civil servants. In addition, these materials support the science of studying nature. The implication of the materials is important for the teacher candidates to teach the primary school students. These primary school students think concretely so that the teacher candidates must master the fundamental concepts. The natural feature of science is to understand the nature and the world. Thus, the teacher candidates must master the material content (Aydede, 2022).

The data analysis result found a higher influence of TCK toward TPACK than TPK toward TPACK. TPK deals with the teaching and technological understanding of teachers in the learning process. TPK also deals with teacher's knowledge and understanding in selecting appropriate media and technology for the learning process. On the other hand, TCK deals with teacher material and technological masteries. The teachers must master the basic concepts of science material; teach abstract science material concretely using appropriate media; and explain the application of science in everyday life so that students' understanding is more concrete. The teachers must sort out the appropriate media and learning methods.

The teacher's pedagogical ability requires habituation. In this research, the teacher candidates required more learning. This situation made their TPK lower than CPK. The teacher's ability to create an excellent learning environment requires trust from the teacher (Munna & Kalam, 2021). Pedagogy deals with student-centered teaching (Shah & Sanothimi, 2021). Mastery of student characteristics requires more skills for teacher candidates. Therefore, teacher candidates need to learn a lot. Fariyani et al. (2020) showed the highest ability to measure teacher PCK was observable on the concept determination component. This component influenced the teachings of the concepts. Their understanding of Primary School Education was excellent because they received teachings with the concept of inquiry and science practicum (Masfuah & Fakhriyah, 2017).

In science learning innovation courses, TPK deals with lesson designs, lesson plans, and teaching simulations. Before teaching, the teacher candidates prepared a lesson plan. Initially, they made the lesson designs with their groups. They also received some practices of learning community. They also discussed and brainstormed based on the applied regulations at schools. After that, the students made lesson plans and taught the materials in a simulation practice. In this session, communication and peer dynamics were very influential in providing input on strengthening teacher performance (Virtue et al., 2019). The school culture supports professional collaboration to manage difficulties and support their peers (Antinluoma et al., 2018). Teacher enthusiasm also increased student learning achievement (Dogan & Julian, 2021).

In the TCK competence, the assessed activities were the results of making worksheets, teaching materials, learning media, and problem-solving tests associated with the literacy phenomenon. Implementing learning by adopting research-based activities provides opportunities for students to connect theoretical concepts with everyday life and to create innovative learning programs (Granjeiro, 2019). This competency deals with the deliverd materials for students. The materials applied innovative learning media, concrete material, examples of equipment, and daily activities related to the studied science material. Science is an abstract concept that requires analysis to create learning (Wong et al., 2020). Indonesian students' survey found that students liked practical learning with real-life relevance (Rohandi, 2017).

TCK results were more influential than TPK because the teacher candidates attempted to be excellent teachers. Thus, they did not understand students comprehensively. The teacher candidates also could not master the current learning. In this research, TCK dealt a lot with students' understanding of the presented materials. The cognitive aspects of students based on the material mastery were better than the aspects of teaching skills. This proved the dominant influence of cognitive factors over the skill factor although both factors were collaborative and important to create exciting learning. Science is an abstract concept so it requires a specific strategy for providing materials. Science also needs specific cognitive strategies, such as concrete examples, practicum, elaboration, and dual codes (Weinstein et al., 2018). Therefore, the teacher's initial concept must be excellent.

Figure 2 shows a linear correlation between TPK competence and TPACK while Figure 3 shows a linear correlation between TCK and TPACK. The two figures explain that if the TPK and TCK abilities are high, then the TPACK is also high. Students' TPK, TCK, and TPACK abilities were varied. However, from the results, TCK provides a higher influence on TPACK than TPK. TCK deals with the implementation of technology in a discipline and the effect of technological development on certain disciplines. The implementation of certain technology influences the studied materials by the students.

TPK dealt with the implementation of technology in the learning process. In this case, the teacher sorted out the media and the implementation of appropriate technology for learning. Based on these data, prospective teachers must have excellent competencies as teachers based on the 21st-century demands, such as the aspects of knowledge rather than

teaching methods. Mastery of material, understanding of material, and capability to combine material with the implementations of media and technology are important to deliver the learning for the students. This matter is the most influential aspect of a teacher's TPACK ability because science is related to abstract concepts. Therefore, students must receive concrete knowledge with the assistance of media and technology to realize comprehensive understanding and master abstract concepts. Science is considered an abstract science by society so it must be studied with some relevant techniques and media to facilitate the students' understanding (Prahani, 2022).

In terms of organizing learning, one's knowledge, insight, and intelligence greatly influence teaching. Teachers can hone competence in teaching methods and strategies through experiences and learning processes, in-house training activities, and an understanding of student characteristics and the environment. The other effort to organize the learning is understanding the complex materials. Therefore, teachers must receive meaningful science learning opportunities with support from all parties to establish excellent pedagogy and provide learning experiences for students (Fitzgerald & Smith, 2016). This matter is correlated to individual intelligence and conceptual mastery. A teacher with excellent conceptual mastery could explain the material content, provide direct experience for the student, create real-daily life concrete material examples, and ensure the students' understanding based on the given materials. The teacher's pedagogy ability deals with teaching practices and theories understood by the teacher (Arnold & Mundy, 2020). Collaborative problem-solving is a critical cognitive skill for prospective teachers (Wismath & Orr, 2015). Information-seeking skills and knowledge-method research can be fostered in university courses (Afdal & Spernes, 2018; Nagatsu et al., 2020; Wenglein et al., 2015).

The applicable curriculum also highly influenced TCK's competence more than TPK. The undergraduate curriculum at TTIs did not intend to prepare teachers but to prepare prospective teachers. In this research, the applied curriculum prepared the prospective teachers in teacher professional education. The prospective teachers could pursue this professional education after they graduate from the undergraduate program. The purpose of this professional education is to realize excellent and faithful teachers proven with the certification of educators. Teachers need continuous professional development to hone primary school students' science teaching skills (Garraway-Lashley, 2019). In addition, the educational level of science teachers must equip students with knowledge and skills (Cakir, 2008). Integrating material into science learning requires particular-expertise (Cabrera et al., 2023). In addition, teachers must provide more motivation to students inside and outside the learning context so that student learning outcomes are maximized (Alcivar et al., 2020). Therefore, at the undergraduate level, TCK is more important than TPK.

5. Conclusions and Future Research

Based on data analysis and discussion, TCK and TPK had an effect of 98.3% toward TPACK. TPK had an effect of 45.2% toward TPACK. TPK had an effect of 52.4% toward TPACK. Thus, the researchers concluded TCK had more effects on TPACK than TPK. Competence related to mastery of concepts, material, application of material in everyday life, and delivery of material are more influential than student mastery in terms of learning.

The researchers recommend lecturers prepare students with more Technological Content Knowledge abilities than Technological Pedagogical Knowledge abilities because Technological Content Knowledge has more influence on Technological Pedagogical Content Knowledge than Technological Pedagogical Knowledge. This research only used survey research for all students of the primary school teacher education study program. Future research should measure all students' Technological Pedagogical Content Knowledge abilities to obtain more valid data. It should measure Technological Pedagogical Knowledge and Technological Content Knowledge and analyze all components of Technological Pedagogical Content Knowledge to obtain more detailed data. In addition, this can be achieved through professional development programs, workshops, and ongoing training opportunities for the teachers development and in line with the education policy and their needs.

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Ethical considerations

Ethical permission was obtained from the Institute for Research and Community Service, Universitas Muria Kudus, Ref. No. 172/LPPM.UMK/B.09.128/V/2023. Written informed consent was obtained from all participants before data collection.

Conflict of Interest

There is no conflict of interest in this research.

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