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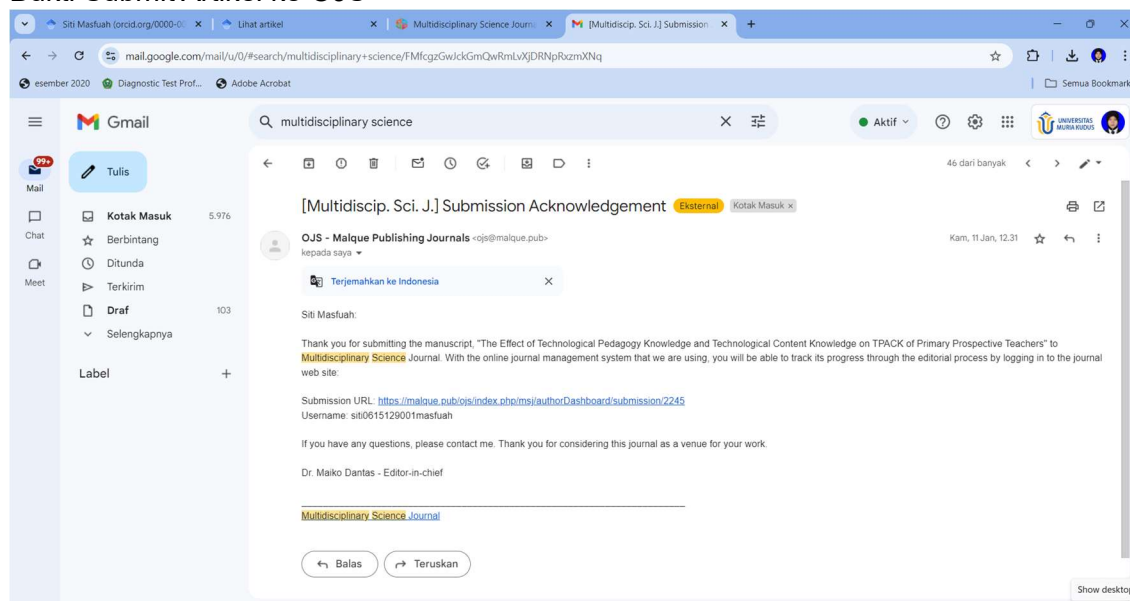
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The Effect of Technological Pedagogy Knowledge and Technological Content Knowledge on TPACK of Primary Prospective Teachers



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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 $Y = 1.752 + 0.452X_1 + 0.524X_2$. 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: technological pedagogy content knowledge, technological pedagogy knowledge, TPACK, primary prospective teacher, 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 development of teacher and student experiences in learning is 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) from 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.

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 prospective primary school teacher students 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. The students 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 students.

Many studies attempted to improve the TPACK ability of teachers and prospective teachers. For example, Fakhriyah et al. (2017) found 33.8% of students had a functional level while 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) explained that looking for relationships 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. From the background, the current research measured the influence of material mastery competence (TCK) and teaching methods (TPK) toward the TPACK of prospective teacher students.

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).

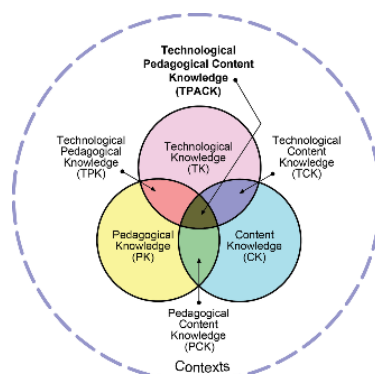


Figure 1 TPACK Framework

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 convey the knowledge and substance to 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 easy 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. 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 prospective primary school teachers 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 indicates the rejection toward 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. 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 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.

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)

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

- Ho₁: TPK has no significant effect on TPACK.
- Ha₁: TPK simultaneously has a significant effect on TPACK.
- Ho₂: TCK has no significant effect on TPACK.
- Ha₂: TCK simultaneously has a significant effect on TPACK.

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 $Y = 1.752 + 0.452X_1 + 0.524X_2$.

From the analyses, the researchers concluded the correlation of the variables based on the R-square values. Table 5 shows the results.

Table 5 R Square		
Components	R Square	Category
TPK	0.452	Weak
TCK	0.524	Moderate
TPK & TCK	0.983	Substantial

The table shows the ability of TPK and TCK for each student is different. Figure 1 and Figure 2 show the influence of TCK on TPACK.

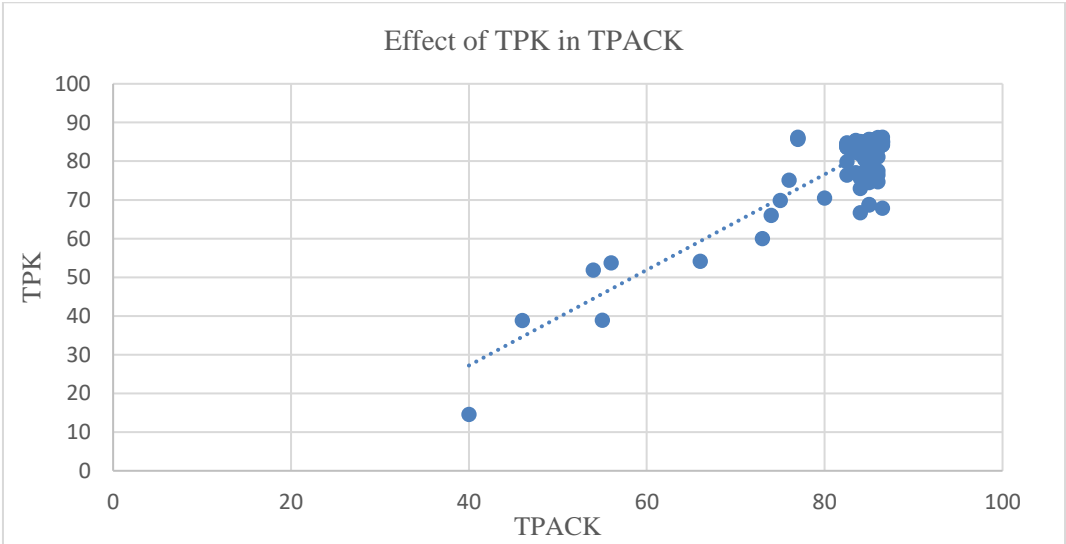


Figure 2 Effect Of TPK in TPACK

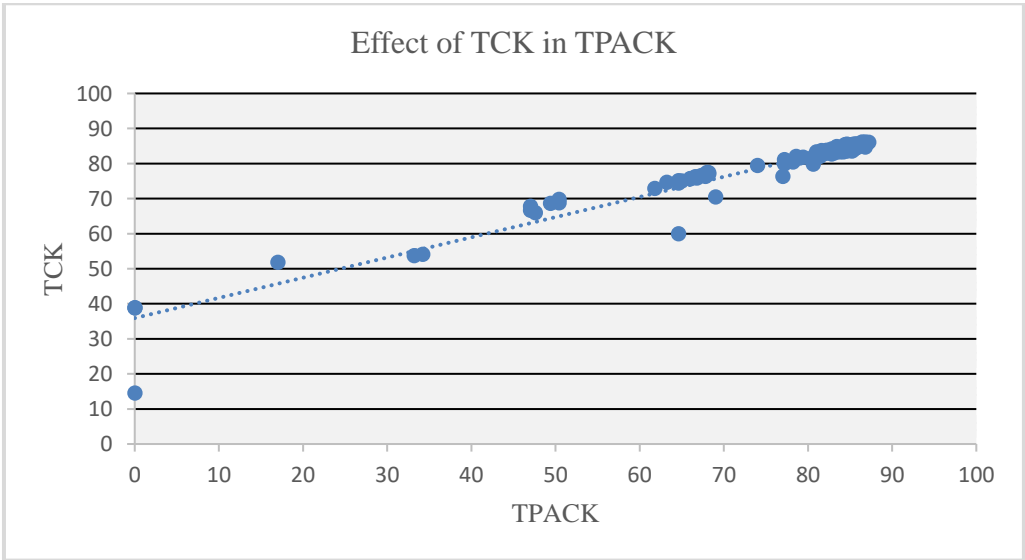


Figure 3 Effect of TPK in TPACK

4. Discussion

Teachers must be literate to apply various devices and media for learning. This matter covers 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 lead to high TPACK competency. 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. In this case, the teacher adapted 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 prospective teacher students 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 TPACK 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 prospective teacher students 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 prospective teacher students to teach the primary school students. These primary school students think concretely so that the prospective teacher students must master the fundamental concepts. The natural feature of science is to understand the nature and the world. Thus, the prospective teacher students 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 prospective teacher students 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 is concerned with student-centered teaching (Shah & Sanothimi, 2021). Mastery of student characteristics requires more skills for prospective students. Therefore, prospective teacher students 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 dealt with lesson designs, lesson plans, and teaching simulations. Before teaching, the prospective teacher students 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 provided opportunities for students to connect theoretical concepts with everyday life and to create innovative learning programs (Granjeiro, 2019). This competency deals with the material delivered to students. The materials applied innovative learning media, concrete material, examples of equipment, and daily activities related to the science material being studied. 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 prospective teachers attempted to learn to be excellent teachers. Thus, they did not understand students in more detail. The prospective teachers 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, interleaving practicum, elaboration, and dual coding (Weinstein et al., 2018). Therefore, the teacher's initial concept must be excellent.

Figure 1 shows a linear correlation between TPK competence and TPACK while figure 2 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 provided 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 mix 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 concrete material examples based on daily life, 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.

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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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References

- Abdullateef, S., T. (2021). Remote Learning: Fostering Learning of 21st Century Skills through Digital Learning Tools. *Arab World English Journal*, 7(1), 190–201. <https://doi.org/10.24093/awej/call7.14>
- Albeta, S. W., Firdaus, L. N., Copriady, J., & Alimin, M. (2023). TPACK-based blended learning as an implementation of progressivism education: A systematic literature review. *Jurnal Pendidikan Vokasi*, 13(1), 44–59. <https://doi.org/10.21831/jpv.v13i1.51287>
- Alcivar, Carmen Magdalena Mero, Tatiana Lizeth Ibarra Quimi, M. F. Z. B. c. (2020). The motivation and its importance in the teaching-learning process. *International Research Journal of Management, IT and Social Sciences*, 7(1), 138–144. <https://doi.org/10.21744/irjmis.v7n1.832>
- Almonacid-Fierro, A. (2023). *International Journal of Educational Methodology Analysis of Pedagogical Content Knowledge in Science Teacher Education: A Systematic Review 2011-2021*. 9(3), 525–534.
- Antinluoma, M., Ilomaki, L., Lahti-Nuuttila, P., & Toom, A. (2018). Schools as Professional Learning Communities. *Journal of Education and Learning*, 7(5), 76. <https://doi.org/10.5539/jel.v7n5p76>
- Anud, Edgar and Caro, V. (2022). Teaching Performance of Science Teachers in the New Normal and Their Technological Pedagogical and Content Knowledge (Tpack) Self-Efficacy. *International Journal of Applied Science and Research*, 05(04), 81–84. <https://doi.org/10.56293/ijasr.2022.5410>
- Arnold, J., & Mundy, B. (2020). Praxis pedagogy in teacher education. *Smart Learning Environments*, 7(1). <https://doi.org/10.1186/s40561-020-0116-z>
- Aydede, M. N. (2022). Examining the Primary School Teacher Candidates' Science Learning Skills in Terms of Their Attitudes towards Science and Their Science Teaching Self-Efficacy Beliefs. *International Journal of Educational Methodology*, 8(4), 853–864. <https://doi.org/10.12973/ijem.8.4.853>
- Cabrera, L., Diane Jass Ketelhut, Kelly Mills, Heather Killen, Merijke Coenraad, Virginia L. Byrne, J. D. P. (2023). Designing a Framework for Teachers' Integration of Computational Thinking into Elementary Science. *Journal of Research in Science Teaching in Science Education*, June. <https://doi.org/10.1002/tea.21888>
- Cakir, M. (2008). Constructivist approaches to learning in science and their implication for science pedagogy: A literature review. *International Journal of Environmental and Science Education*, 3(4), 193–206.
- Creswell, J. W., & Creswell, J. D. (2018). Mixed Methods Procedures. In *Research Defign: Qualitative, Quantitative, and Mixed M ethods Approaches*.
- Doğan, S., & Julian, D. (2021). Collaborative Community Problem Solving: A Model and Recommendations to Support

- Community Practice. Ahi Evran Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 7(1), 1–14. <https://doi.org/10.31592/aeusbed.676547>
- Fakhriyah, F., Masfuah, S., Hilyana, F. S., & Mamat, N. (2022). Analysis of Technological Pedagogical Content Knowledge (Tpack) Ability Based on Science Literacy for Pre-Service Primary School Teachers in Learning Science Concepts. *Jurnal Pendidikan IPA Indonesia*, 11(3), 399–411. <https://doi.org/10.15294/jpii.v11i3.37305>
- Fakhriyah, F., Masfuah, S., Roysa, M., Rusilowati, A., & Rahayu, E. S. (2017). Student's science literacy in the aspect of content science? *Jurnal Pendidikan IPA Indonesia*, 6(1), 81–87. <https://doi.org/10.15294/jpii.v6i1.7245>
- Fariyani, Q., Mubarak, F. K., Masfu'ah, S., & Syukur, F. (2020). Pedagogical Content Knowledge of Pre-service Physics Teachers. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 9(1), 99–107. <https://doi.org/10.24042/jipfalbiruni.v9i1.3409>
- Fitzgerald, A., & Smith, K. (2016). Science that matters: Exploring science learning and teaching in primary schools. *Australian Journal of Teacher Education*, 41(4), 64–78. <https://doi.org/10.14221/ajte.2016v41n4.4>
- Garraway-Lashley, Y. M. (2019). Teaching Science at the Primary school Level: "Problems Teachers' are facing". *Asian Journal of Education and E-Learning*, 7(3), 81–94. <https://doi.org/10.24203/ajeel.v7i3.5847>
- Gopo, C. (2022). The Role of Technology in the Architecture of the 21st Century. *The Official Research Journal of Tagum City Division*.
- Granjeiro, É. M. (2019). Research-based teaching-learning method: A strategy to motivate and engage students in human physiology classes. *Advances in Physiology Education*, 43(4), 553–556. <https://doi.org/10.1152/advan.00034.2019>
- Hair, J. F., Ringle, C. M., & Sarstedt, M. (2013). Partial Least Squares Structural Equation Modeling: Rigorous Applications, Better Results and Higher Acceptance. *Long Range Planning*, 46(1–2), 1–12. <https://doi.org/10.1016/j.lrp.2013.01.001>
- Helaluddin, Fitriyyah, D., Rante, S. V. N., Tulak, H., Ulfah, M., St., & Wijaya, H. (2023). Gen Z students perception of ideal learning in post-pandemic: A phenomenological study from Indonesia. *International Journal of Educational Methodology*, 9(2), 423–434. <https://doi.org/10.12973/ijem.9.2.423>
- Jan, H., (2017). Teacher of 21st Century: Characteristics and Development. *Research on Humanities and Social Sciences*, 7(9), 2225–0484. www.iiste.org
- Joo, Y. J., Park, S., & Lim, E. (2018). Factors Influencing Preservice Teachers' Intention to Use Technology: TPACK, Teacher Self-efficacy, and Technology Acceptance Model. *Journal of Educational Technology & Society*, 21(3), 48–59. <http://www.jstor.org/stable/26458506>
- Kereluik, K., Mishra, P., Fahnoe, C., & Terry, L. (2013). What Knowledge Is of Most Worth. *Journal of Digital Learning in Teacher Education*, 29(4), 127–140. <https://doi.org/10.1080/21532974.2013.10784716>
- Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content (TPACK)? *Journal of Education*, 193(3): 13–19. <https://www.researchgate.net/publication/260281100>
- Koehler, M.J. and Mishra, P. (2008) 'Introducing TPACK. AACTE Committee on Innovation and Technology (Ed.): The Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators, pp.3–29, Lawrence Erlbaum Associates, Mahwah, NJ.
- Koh J. H. L, Ching Sing Chai, & Ching-Chung Tsai. (2014). Demographic Factors, TPACK Constructs, and Teachers' Perceptions of Constructivist-Oriented TPACK. *Journal of Educational Technology & Society*, 17(1), 185–196. <http://www.jstor.org/stable/jeductechsoci.17.1.185>
- Koh, J. H. L., Chai, C. S., & Lim, W. Y. (2017). Teacher Professional Development for TPACK-21CL: Effects on Teacher ICT Integration and Student Outcomes. *Journal of Educational Computing Research*, 55(2), 172–196. <https://doi.org/10.1177/0735633116656848>
- Koh, J. H. L., Chai, C. S., Benjamin, W., & Hong, H. Y. (2015). Technological Pedagogical Content Knowledge (TPACK) and Design Thinking: A Framework to Support ICT Lesson Design for 21st Century Learning. *Asia-Pacific Education Researcher*, 24(3), 535–543. <https://doi.org/10.1007/s40299-015-0237-2>
- Kuloğlu, A., & Karabekmez, V. (2022). The Relationship Between 21st-century Teacher Skills and Critical Thinking Skills of Classroom Teacher. In *International Journal of Psychology and Educational Studies* (Vol. 9, Issue 1, pp. 91–101). <https://doi.org/10.52380/ijpes.2022.9.1.551>
- Kumari, K., & Yadav, S. (2018). Linear regression analysis study. *Journal of the Practice of Cardiovascular Sciences*, 4(1), 33. https://doi.org/10.4103/jpcs.jpcs_8_18
- Masfuah, S., & Fakhriyah, F. (2017). The Aspect of Science Literacy for Students of Elementary School Education Program Through the Application of Project Based Learning. *Unnes Science Education Journal*, 6(3), 1708–1716. <http://journal.unnes.ac.id/sju/index.php/usej%0ADEVELOPING>

- Messina, L., & Tabone, S. (2012). Integrating Technology into Instructional Practices Focusing on Teacher Knowledge. *Procedia - Social and Behavioral Sciences*, 46(2011), 1015–1027. <https://doi.org/10.1016/j.sbspro.2012.05.241>
- Munna, A. S., & Kalam, M. A. (2021). Teaching and learning process to enhance teaching effectiveness: literature review. *International Journal of Humanities and Innovation (IJHI)*, 4(1), 1–4. <https://doi.org/10.33750/ijhi.v4i1.102>
- OECD. (2020). Technical Report 2022. (2022).
- Okoye, K., Arrona-Palacios, A., Camacho-Zuñiga, C., Hammout, N., Nakamura, E. L., Escamilla, J., & Hosseini, S. (2020). Impact of students evaluation of teaching: a text analysis of the teachers qualities by gender. *International Journal of Educational Technology in Higher Education*, 17(1). <https://doi.org/10.1186/s41239-020-00224-z>
- Önen, Z., & Sincar, M. (2019). An analysis of teacher's performance evaluation at private schools: Kahramanmaraş and gaziantep sample. *Educational Administration: Theory and Practice*, 25(1), 169–190. <https://doi.org/10.14527/kuey.2019.005>
- Prahani, B. K., Amiruddin, M. Z., Suprpto, N., Deta, U. A., & Cheng, T. H. (2022). The trend of physics education research during COVID-19 pandemic. *International Journal of Educational Methodology*, 8(3), 517–533. <https://doi.org/10.12973/ijem.8.3.517>
- Rohandi, R. (2017). Teaching and Learning Science: Students' Perspective. *International Journal of Indonesian Education and Teaching*, October, 16–31. <https://doi.org/10.24071/ijiet.2017.010103>
- Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, 46(8), 909–921. <https://doi.org/10.1002/tea.20327>
- Sojanah, J., Suwatno, Kodri, & Machmud, A. (2021). Factors affecting teachers' technological pedagogical and content knowledge (A survey on economics teacher knowledge). *Cakrawala Pendidikan*, 40(1), 1–16. <https://doi.org/10.21831/cp.v40i1.31035>
- Suganda, H., Riandi, R., & Purwianingsih, W. (2021). TPACK perception analysis of teachers in facing 21st-century learning. *Jurnal Bioedukatika*, 9(2), 93. <https://doi.org/10.26555/bioedukatika.v9i2.17788>
- Susanti, N., Hadiyanto, & Mukminin, A. (2022). The Effects of TPACK Instrument Variables on Teacher Candidates in Higher Education. *Journal of Higher Education Theory and Practice*, 22(2). <https://doi.org/10.33423/jhetp.v22i2.5041>
- Tsekhmister, Y. (2022). Effectiveness of Practical Experiences in Using Digital Pedagogies in Higher Education: A Meta-Analysis. *Journal of Higher Education Theory and Practice*, 22(15), 138–150. <https://doi.org/10.33423/jhetp.v22i15.5567>
- Ucak, E. (2019). "Science teaching and science teachers" from students' point of view. *International Journal of Educational Methodology*, 5(2), 221–233. <https://doi.org/10.12973/ijem.5.2.221>
- Virtue, E., Maddox, G., & Pfaff, K. (2019). The Lasting Effects of Learning Communities. *Learning Communities Research and Practice*, 7(2), 6.
- Weinstein, Y., Madan, C. R., & Sumeracki, M. A. (2018). Teaching the science of learning. *Cognitive Research: Principles and Implications*, 3(1). <https://doi.org/10.1186/s41235-017-0087-y>
- Wismath, S. L., & Orr, D. (2015). The Canadian Journal for the Scholarship of Teaching and Learning Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning. *The Canadian Journal for the Scholarship of Teaching and Learning*, 6(3). http://ir.lib.uwo.ca/cjsotl_rcacea%5Cnhttp://ir.lib.uwo.ca/cjsotl_rcacea/vol6/iss3/10
- Wong, C. L., Chu, H. E., & Yap, K. C. (2020). A Framework for Defining Scientific Concepts in Science Education. *Asia-Pacific Science Education*, 6(2), 615–644. <https://doi.org/10.1163/23641177-bja10010>
- Young, J.R. (2016). Unpacking TPACK in Mathematics education research: A systematic review of meta-analyses. *International Journal of Educational Methodology*, 2(1), 19–29. <https://doi.org/10.12973/ijem.2.1.19>
- Afdal, H. W., & Spernes, K. (2018). Designing and redesigning research-based teacher education. *Teaching and Teacher Education*, 74, 215–228.
- Nagatsu, M., Davis, T., DesRoches, C. T., Koskinen, I., MacLeod, M., Stojanovic, M., & Thorén, H. (2020). Philosophy of science for sustainability science. *Sustainability Science*, 15, 1807–1817.
- Wenglein, S., Bauer, J., Heininger, S., & Prenzel, M. (2015). Kompetenz angehender Lehrkräfte zum Argumentieren mit Evidenz: Erhöht ein Training von Heuristiken die Argumentationsqualität. *Unterrichtswissenschaft*, 43(3), 209–224.

2. Permohonan Melengkapi Metadata Author

The screenshot shows a web browser window with multiple tabs. The active tab is titled 'Masfiah et al. | The effect of te...'. The address bar shows the URL 'malque.pub/ojs/index.php/msj/authorDashboard/submission/2245'. The browser's address bar also displays 'esember 2020', 'Diagnostic Test Prof...', and 'Adobe Acrobat'. The page content is from 'Multidisciplinary Science Journal' and includes a 'Back to Submissions' link. A modal window titled 'Author data request - Multidiscip. Sci. J.' is open, displaying the following information:

Participants
Editor (editor)
Siti Masfiah (siti0615129001masfiah)

Messages

Note	From
<p>Author data request - Multidiscip. Sci. J.</p> <p>Dear Dr. Siti Masfiah,</p> <p>Thank you for your article submission to the Multidisciplinary Science Journal.</p> <p>We note that in your original submitted manuscript, there are other authors. However, in our system, only one author of this list was inserted.</p> <p>Due to this issue, we kindly request that you add all remaining authors of your article within five days of this date so we can proceed with the process. Please don't forget to add all the details (full name, email, country, institution...).</p> <p>We appreciate your understanding and are awaiting the complete author list.</p> <p>Best Regards,</p> <p><i>Malque Publishing Team</i> <i>Multidisciplinary Science Journal</i></p>	<p>editor 2024-01-11 06:43 PM</p>

3. Metadata dan Orcid telah diperbaiki

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Masfiah et al. | The effect of te...

Vol. 6 No. 10 (2024): October | ...

The effect of technological peo...

[Multidiscip. Sci.] New notific...

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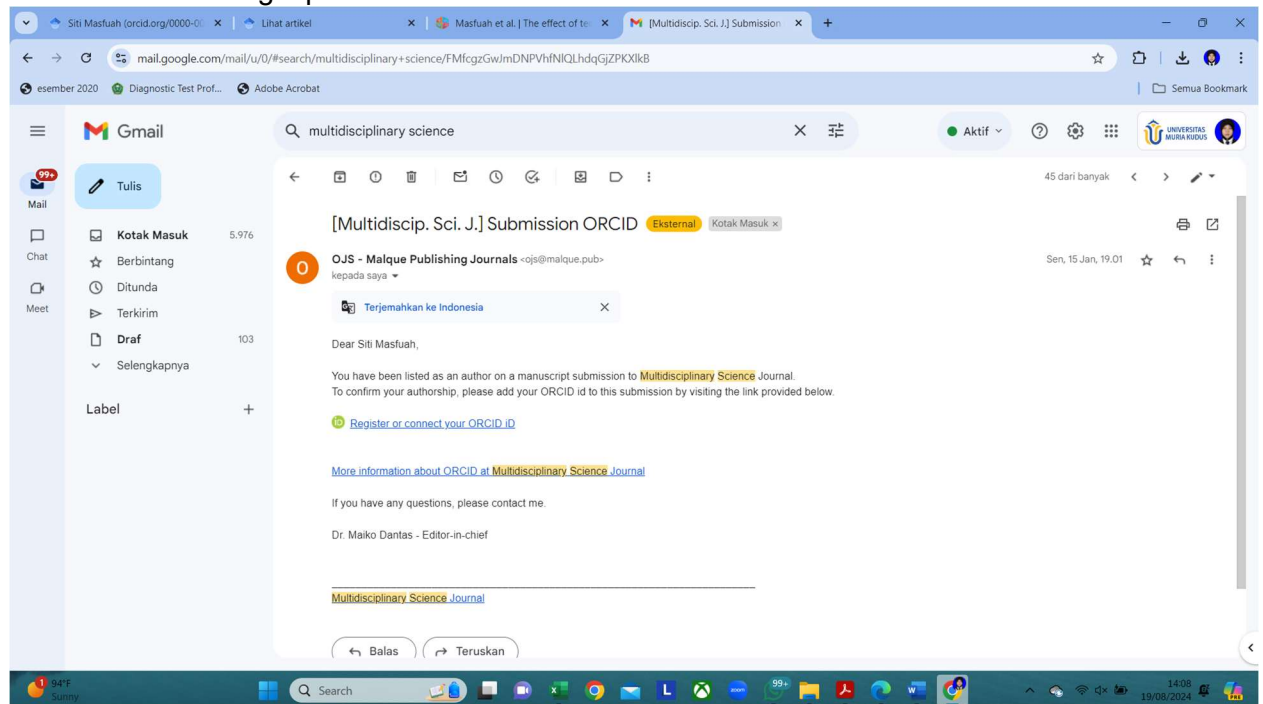
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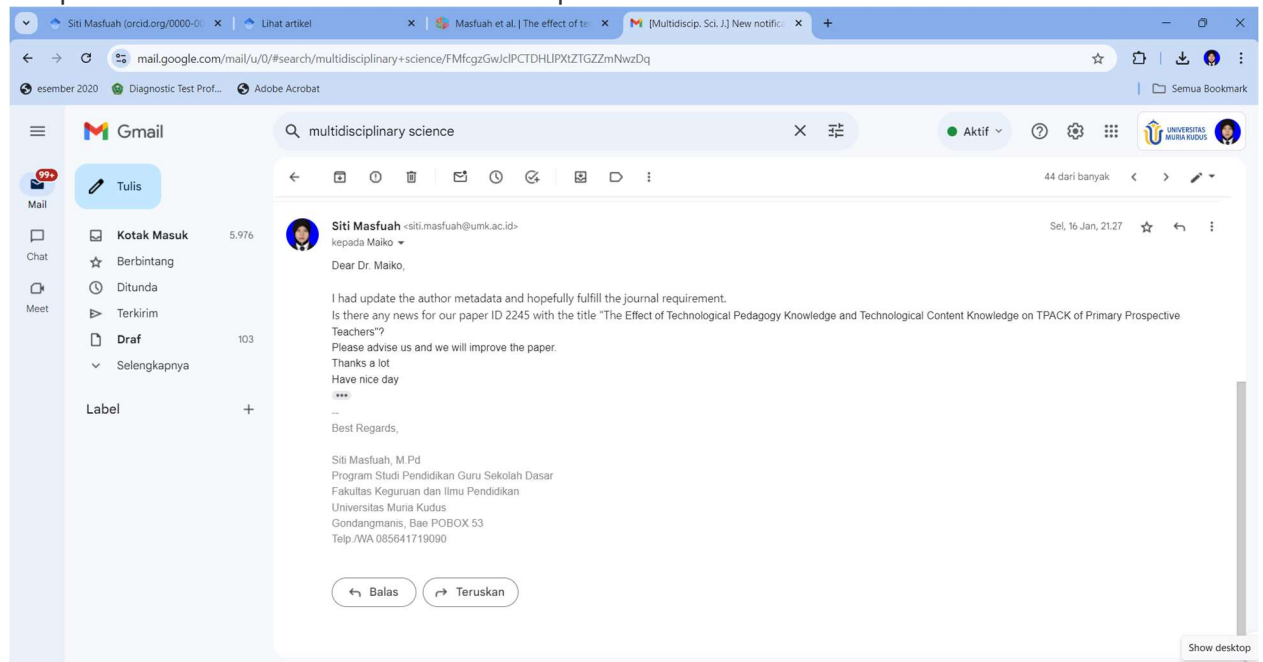
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3. Permohonan Melengkapi Data Orcid



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5. Pemberitahuan Masuk Tahap Pre-review

The screenshot shows a web browser window with multiple tabs. The active tab is 'Masfuah et al. | The effect of te...', and the address bar shows 'malque.pub/ojs/index.php/msj/authorDashboard/submission/2245'. The page title is 'Multidisciplinary Science Journal'. A modal window titled 'Author data request' is open, displaying a message from the editor.

Author data request

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Messages

Note	From
Dear Editor, I had update the author metadata and hopefully fulfill the journal requirement. Thank you	siti0615129001masfuah 2024-01-16 02:18 PM
Dear Dr. Siti Masfuah, An editor has already been assigned to your article to evaluate it at this pre-review stage. The editor is currently dealing with several papers at this stage and will soon contact you and issue an editorial decision on your manuscript. I kindly ask you to wait for the Editor. Best Regards, Malque Publishing Team Multidisciplinary Science Journal	editor 2024-01-16 06:15 PM

6. Pemberitahuan Lolos Pre-review dan Permintaan Reviewer

The screenshot displays the author dashboard for the Multidisciplinary Science Journal. The main content area shows a message from the editor regarding the pre-review of the manuscript "The Effect of Technological Pedagogy Knowledge and Technological Content Knowledge on TPACK of Primary Prospective Teachers". The message states that the pre-review is complete and the article is well-structured, ready to be sent to reviewers. It also includes a request for the author to suggest at least three potential reviewers by February 15, 2024.

Participants

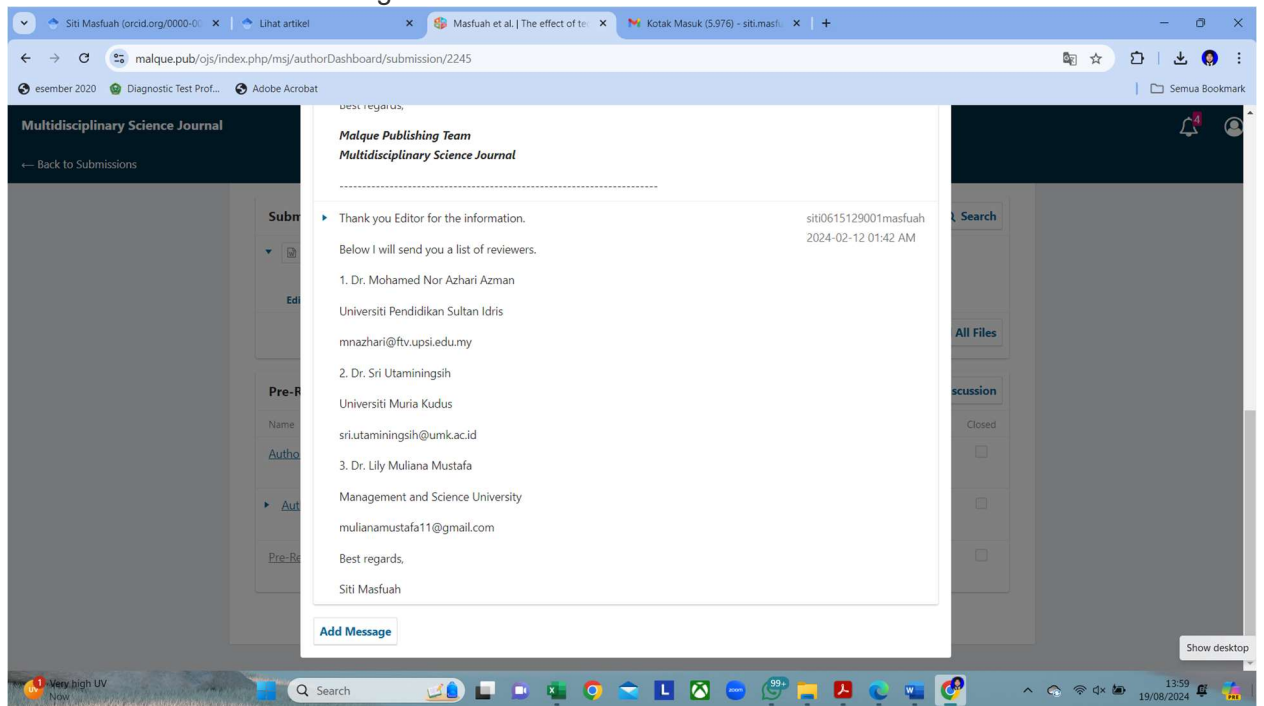
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Messages

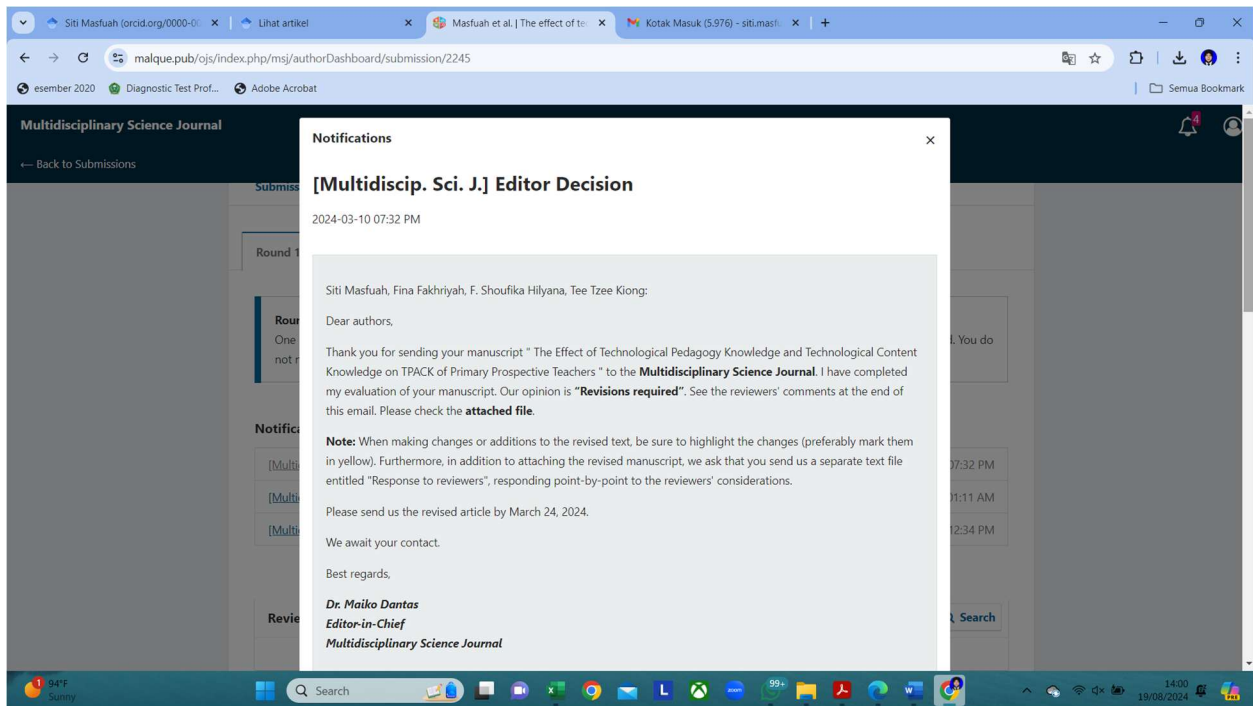
Note	From
Initial adjustments - Multidiscip. Sci. J. Dear Dr. Siti Masfiah: Thank you for submitting your article to the Multidisciplinary Science Journal . I have completed my pre-review evaluation of your manuscript "The Effect of Technological Pedagogy Knowledge and Technological Content Knowledge on TPACK of Primary Prospective Teachers". Congratulations your article is well structured and adequately adjusted to the norms of our journal. It needs no initial adjustments and is ready to be sent to reviewers.	editor 2024-02-10 11:25 AM

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When doing so, please inform the **name, email, institution, and country** of the suggested reviewers.
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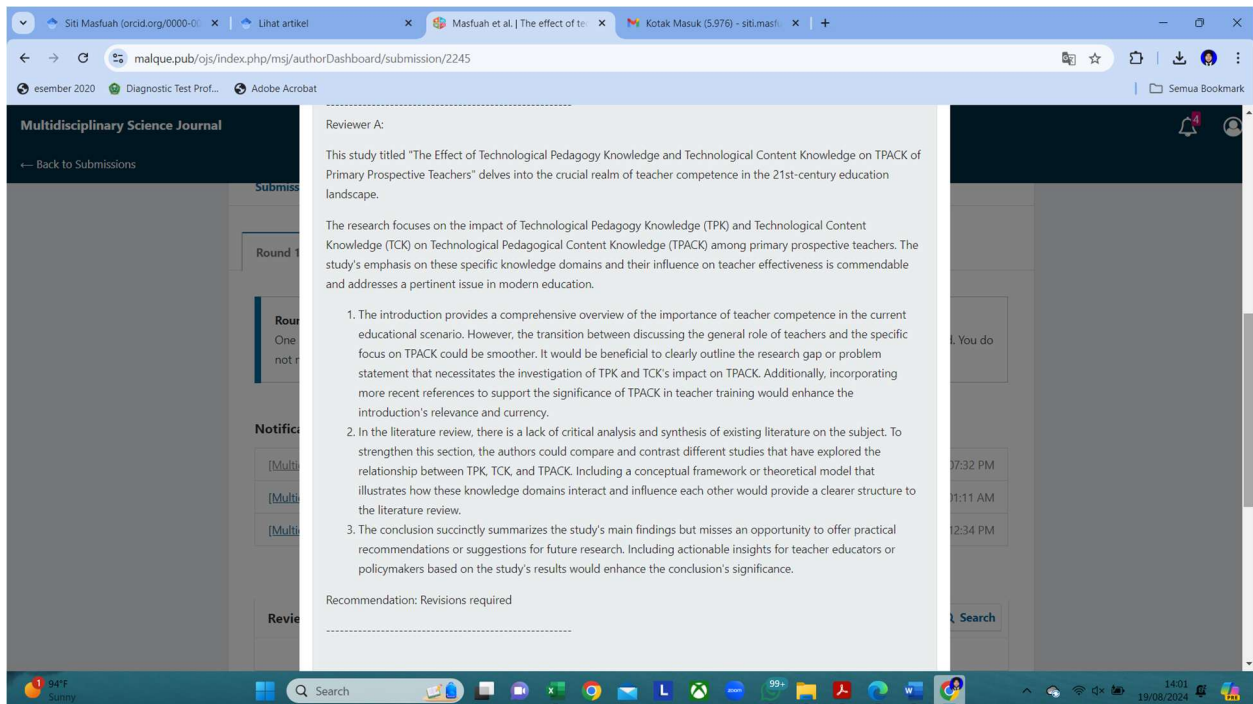
7. Jawaban Author Perihal Penugasan Reviewer



8. Hasil Review Isi Artikel



Review dari Reviewer 1



Review dari reviewer 2

The screenshot shows a web browser window with multiple tabs. The active tab is titled "Masfiah et al. | The effect of te...". The address bar shows the URL "malque.pub/ojs/index.php/msj/authorDashboard/submission/2245". The page content is from "Multidisciplinary Science Journal" and displays a submission page with a review overlay. The overlay contains the following text:

recommendations or suggestions for future research. Including actionable insights for teacher educators or policymakers based on the study's results would enhance the conclusion's significance.

Recommendation: Revisions required

Reviewer B:

In conclusion, the study makes a valuable contribution to the understanding of TPACK among primary prospective teachers.

The methodology has a limited discussion on the rationale behind choosing specific data collection instruments or the sampling strategy employed. Providing a justification for the selection of instruments and participants would enhance the methodological rigor of the study.

By addressing this, the study has the potential to make a more significant impact.

Recommendation: Revisions required

[Multidisciplinary Science Journal](#)

The browser's taskbar at the bottom shows the date and time as 14:02 on 19/08/2024, along with various system icons and open applications.

9. Revisi Artikel Diupload ke OJS

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15412	Respond to Reviewer Report_MJS.docx	March 17, 2024	Supplementary Material
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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 $Y = 1.752 + 0.452X_1 + 0.524X_2$. 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: technological pedagogy content knowledge, technological pedagogy knowledge, TPACK, primary prospective teacher, 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 development of teacher and student experiences in learning is 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) from 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 skills 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 prospective primary school teacher students 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. The students 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 students.

Many studies attempted to improve the TPACK ability of teachers and prospective teachers. For example, Fakhriyah et al. (2017) found 33.8% of students had a functional level while 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) explained that looking for relationships 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 realm 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 prospective teacher students.

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).

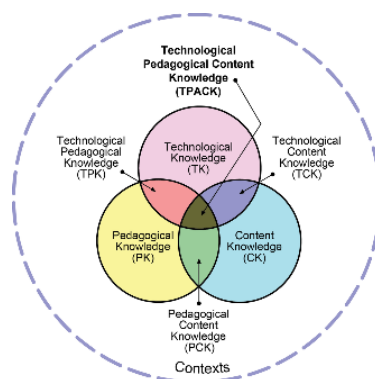


Figure 1 TPACK Framework

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 convey the knowledge and substance to 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).

74

75 **3. Materials and Methods**

76

77 This research measured the effect of TPK (Technological Pedagogy Knowledge) and TCK (Technological Content

78 Knowledge) on TPACK (Technological Pedagogy Content Knowledge) in the college students of the primary school teacher

79 education program at Muria Kudus University. These students were the candidates of primary school teachers. This

80 quantitative applied a survey research design with a correlational method (Cresswell, 2018).

81

82 *3.1. Sample and Data Collection*

83

84 The research population consisted of 262 students in the fifth semester of 2022/2023. The researchers selected the

85 subjects with random sampling. The results were 150 college students in the fifth semester, the year 2022/2023. They took

86 science learning innovation courses. The independent variables were TPK and TCK while the dependent variable was TPACK.

87 The applied instruments were easy test questions, projects, and performance observation sheets to measure the lesson design,

88 teaching simulations, worksheets, teaching materials, learning media, assessment instruments, lesson plans, and problem-

89 solving tests (Hilyana et al., 2023; Fakhriyah et al., 2022). After obtaining the data, the researchers grouped the data into two

90 competencies. The first one was TPK, consisting of lesson design, lesson plans, and teaching simulations. The second group was

91 TCK, consisting of worksheets, teaching materials, learning media, and problem-solving tests

92

93 *2.2. Analyzing of Data*

94

95 After collecting the data, the researchers analyzed the data with multiple regression tests to determine the influence of

96 TPK and TCK toward TPACK of the prospective teacher students (Cresswell, 2018). The regression analysis was useful for

97 calculating the correlation among variables (Kumari & Yadav, 2018). Table 1 shows the square-correlation coefficient as

98 proposed by Hair et al. (2013).

99

100

Table 1 R Square

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

101

102

103 **3. Finding**

104

105 This research measured the influence of TPK and TCK toward TPACK of the prospective primary school teachers at Muria

106 Kudus University. These research subjects took science learning innovation courses in semester 5. This research lasted for a

107 semester. The course consisted of three classes with a total of 150 students. They attended the course for 16 meetings. During

108 this semester, the lecturers shared the material of being excellent science teachers based on TPACK competence qualifications

109 and 21st-century necessities.

110 After collecting the data, the researchers examined the data normality. The results found all data from TPK, TCK, and

111 TPACK had normal distribution based on the mean scores. Then, the researchers promoted regression tests with the assistance

112 of SPSS. This process was useful to determine the multiple linear regression equations of TPK and TCK toward TPACK. Table 2

113 shows the results.

114

115

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			

- 116 a. Dependent Variable: TPACK (Y)
- 117 b. Predictors: (Constant), TCK (X2), TPK (X1)
- 118

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

120 proposed hypotheses:

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

122 Ha: TPK and TCK simultaneously have a significant effect on TPACK.

123

124 Table 2 shows the calculation results from SPSS. The obtained sig-value is 0.000 lower than 0.05. The value indicates the

125 rejection toward 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. 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 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.

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)

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

- Ho₁: TPK has no significant effect on TPACK.
- Ha₁: TPK simultaneously has a significant effect on TPACK.
- Ho₂: TCK has no significant effect on TPACK.
- Ha₂: TCK simultaneously has a significant effect on TPACK.

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 $Y = 1.752 + 0.452X_1 + 0.524X_2$.

From the analyses, the researchers concluded the correlation of the variables based on the R-square values. Table 5 shows the results.

Table 5 R Square

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

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

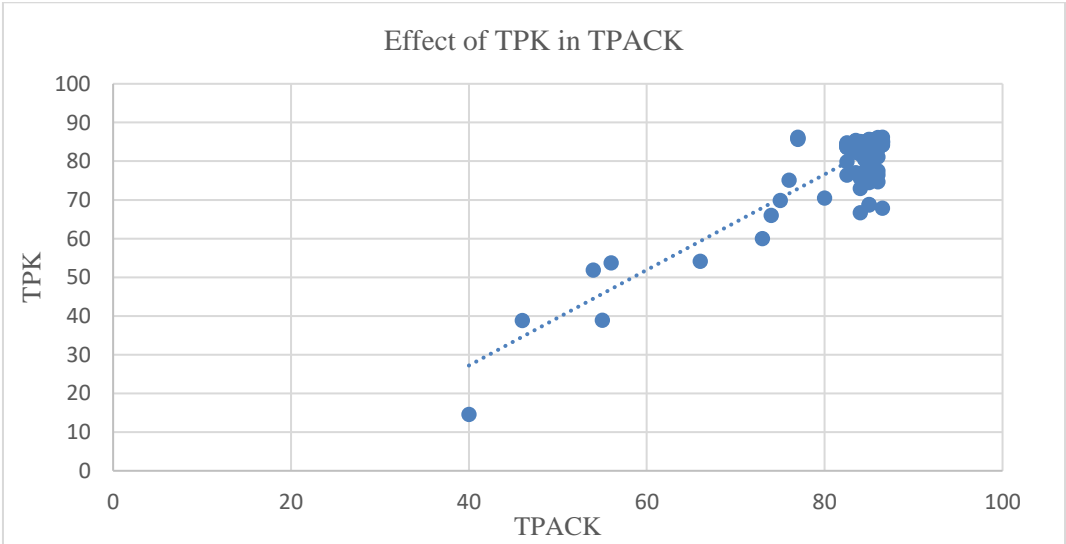


Figure 2 Effect Of TPK in TPACK

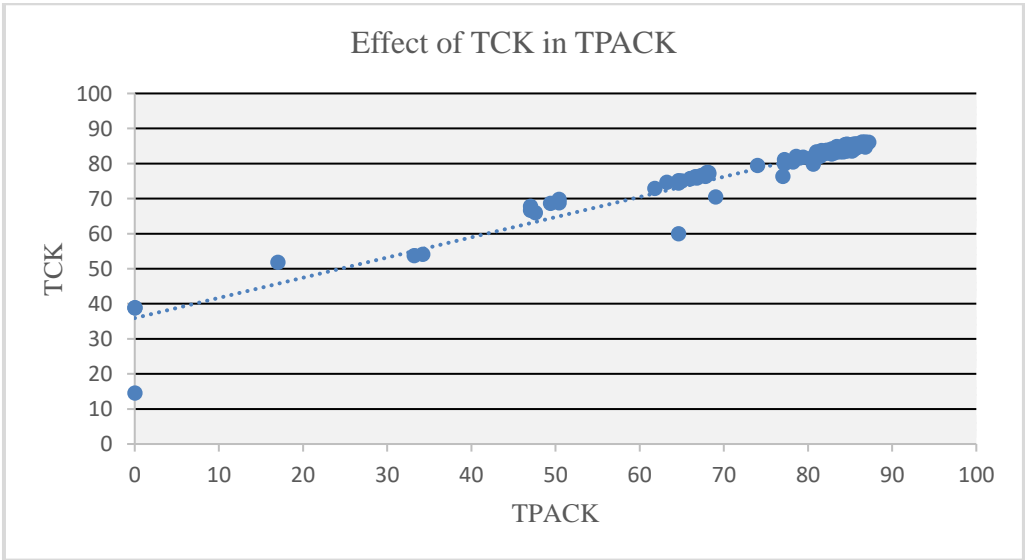


Figure 3 Effect of TPK in TPACK

4. Discussion

Teachers must be literate to apply various devices and media for learning. This matter covers 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 lead to high TPACK competency. 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. In this case, the teacher adapted 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 prospective teacher students 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 TPACK 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 prospective teacher students 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 prospective teacher students to teach the primary school students. These primary school students think concretely so that the prospective teacher students must master the fundamental concepts. The natural feature of science is to understand the nature and the world. Thus, the prospective teacher students 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 prospective teacher students 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 is concerned with student-centered teaching (Shah & Sanothimi, 2021). Mastery of student characteristics requires more skills for prospective students. Therefore, prospective teacher students 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 dealt with lesson designs, lesson plans, and teaching simulations. Before teaching, the prospective teacher students 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 provided opportunities for students to connect theoretical concepts with everyday life and to create innovative learning programs (Granjeiro, 2019). This competency deals with the material delivered to students. The materials applied innovative learning media, concrete material, examples of equipment, and daily activities related to the science material being studied. 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 prospective teachers attempted to learn to be excellent teachers. Thus, they did not understand students in more detail. The prospective teachers 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, interleaving practicum, elaboration, and dual coding (Weinstein et al., 2018). Therefore, the teacher's initial concept must be excellent.

Figure 1 shows a linear correlation between TPK competence and TPACK while figure 2 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 provided 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 mix 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 concrete material examples based on daily life, 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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References

- Abdullateef, S., T. (2021). Remote Learning: Fostering Learning of 21st Century Skills through Digital Learning Tools. *Arab World English Journal*, 7(1), 190–201. <https://doi.org/10.24093/awej/call7.14>
- Albeta, S. W., Firdaus, L. N., Copriady, J., & Alimin, M. (2023). TPACK-based blended learning as an implementation of progressivism education: A systematic literature review. *Jurnal Pendidikan Vokasi*, 13(1), 44–59. <https://doi.org/10.21831/jpv.v13i1.51287>
- Alcivar, Carmen Magdalena Mero, Tatiana Lizeth Ibarra Quimi, M. F. Z. B. c. (2020). The motivation and its importance in the teaching-learning process. *International Research Journal of Management, IT and Social Sciences*, 7(1), 138–144. <https://doi.org/10.21744/irjmis.v7n1.832>
- Almonacid-Fierro, A. (2023). *International Journal of Educational Methodology Analysis of Pedagogical Content Knowledge in Science Teacher Education: A Systematic Review 2011-2021*. 9(3), 525–534.
- Antinluoma, M., Ilomaki, L., Lahti-Nuuttila, P., & Toom, A. (2018). Schools as Professional Learning Communities. *Journal of Education and Learning*, 7(5), 76. <https://doi.org/10.5539/jel.v7n5p76>
- Anud, Edgar and Caro, V. (2022). Teaching Performance of Science Teachers in the New Normal and Their Technological Pedagogical and Content Knowledge (Tpack) Self-Efficacy. *International Journal of Applied Science and Research*, 05(04), 81–84. <https://doi.org/10.56293/ijasr.2022.5410>
- Arnold, J., & Mundy, B. (2020). Praxis pedagogy in teacher education. *Smart Learning Environments*, 7(1). <https://doi.org/10.1186/s40561-020-0116-z>
- Aydede, M. N. (2022). Examining the Primary School Teacher Candidates' Science Learning Skills in Terms of Their Attitudes towards Science and Their Science Teaching Self-Efficacy Beliefs. *International Journal of Educational Methodology*, 8(4), 853–864. <https://doi.org/10.12973/ijem.8.4.853>
- Cabrera, L., Diane Jass Ketelhut, Kelly Mills, Heather Killen, Merijke Coenraad, Virginia L. Byrne, J. D. P. (2023). Designing a Framework for Teachers' Integration of Computational Thinking into Elementary Science. *Journal of Research in Science Teaching in Science Education*, June. <https://doi.org/10.1002/tea.21888>
- Cakir, M. (2008). Constructivist approaches to learning in science and their implication for science pedagogy: A literature review. *International Journal of Environmental and Science Education*, 3(4), 193–206.
- Creswell, J. W., & Creswell, J. D. (2018). Mixed Methods Procedures. In *Research Defign: Qualitative, Quantitative, and Mixed*

Methods Approaches.

- Doğan, S., & Julian, D. (2021). Collaborative Community Problem Solving: A Model and Recommendations to Support Community Practice. *Ahi Evran Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 7(1), 1–14. <https://doi.org/10.31592/aeusbed.676547>
- Fakhriyah, F., Masfuah, S., Hilyana, F. S., & Mamat, N. (2022). Analysis of Technological Pedagogical Content Knowledge (Tpack) Ability Based on Science Literacy for Pre-Service Primary School Teachers in Learning Science Concepts. *Jurnal Pendidikan IPA Indonesia*, 11(3), 399–411. <https://doi.org/10.15294/jpii.v11i3.37305>
- Fakhriyah, F., Masfuah, S., Roysa, M., Rusilowati, A., & Rahayu, E. S. (2017). Student's science literacy in the aspect of content science? *Jurnal Pendidikan IPA Indonesia*, 6(1), 81–87. <https://doi.org/10.15294/jpii.v6i1.7245>
- Fariyani, Q., Mubarak, F. K., Masfu'ah, S., & Syukur, F. (2020). Pedagogical Content Knowledge of Pre-service Physics Teachers. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 9(1), 99–107. <https://doi.org/10.24042/jipfalbiruni.v9i1.3409>
- Fitzgerald, A., & Smith, K. (2016). Science that matters: Exploring science learning and teaching in primary schools. *Australian Journal of Teacher Education*, 41(4), 64–78. <https://doi.org/10.14221/ajte.2016v41n4.4>
- Garraway-Lashley, Y. M. (2019). Teaching Science at the Primary school Level: "Problems Teachers' are facing". *Asian Journal of Education and E-Learning*, 7(3), 81–94. <https://doi.org/10.24203/ajeel.v7i3.5847>
- Gopo, C. (2022). The Role of Technology in the Architecture of the 21st Century. *The Official Research Journal of Tagum City Division*.
- Granjeiro, É. M. (2019). Research-based teaching-learning method: A strategy to motivate and engage students in human physiology classes. *Advances in Physiology Education*, 43(4), 553–556. <https://doi.org/10.1152/advan.00034.2019>
- Hair, J. F., Ringle, C. M., & Sarstedt, M. (2013). Partial Least Squares Structural Equation Modeling: Rigorous Applications, Better Results and Higher Acceptance. *Long Range Planning*, 46(1–2), 1–12. <https://doi.org/10.1016/j.lrp.2013.01.001>
- Helaluddin, Fitriyyah, D., Rante, S. V. N., Tulak, H., Ulfah, M., St., & Wijaya, H. (2023). Gen Z students perception of ideal learning in post-pandemic: A phenomenological study from Indonesia. *International Journal of Educational Methodology*, 9(2), 423–434. <https://doi.org/10.12973/ijem.9.2.423>
- Hilyana, F. S., Fakhriyah, F., & Masfuah, S. (2023, June). Analysis on the ability of primary teacher education lecturers in TPACK-based E-learning. In *AIP Conference Proceedings* (Vol. 2614, No. 1). AIP Publishing.
- Jan, H., (2017). Teacher of 21st Century: Characteristics and Development. *Research on Humanities and Social Sciences*, 7(9), 2225–0484. www.iiste.org
- Joo, Y. J., Park, S., & Lim, E. (2018). Factors Influencing Preservice Teachers' Intention to Use Technology: TPACK, Teacher Self-efficacy, and Technology Acceptance Model. *Journal of Educational Technology & Society*, 21(3), 48–59. <http://www.jstor.org/stable/26458506>
- Koehler, M. J., Mishra, P., Kereluik, K., Shin, T. S., & Graham, C. R. (2014). The technological pedagogical content knowledge framework. *Handbook of research on educational communications and technology*, 101–111.
- Kereluik, K., Mishra, P., Fahnoe, C., & Terry, L. (2013). What Knowledge Is of Most Worth. *Journal of Digital Learning in Teacher Education*, 29(4), 127–140. <https://doi.org/10.1080/21532974.2013.10784716>
- Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content (TPACK)? *Journal of Education*, 193(3): 13–19. <https://www.researchgate.net/publication/260281100>
- Koehler, M.J. and Mishra, P. (2008) 'Introducing TPCK. AACTE Committee on Innovation and Technology (Ed.): The Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators, pp.3–29, Lawrence Erlbaum Associates, Mahwah, NJ.
- Koh J. H. L, Ching Sing Chai, & Ching-Chung Tsai. (2014). Demographic Factors, TPACK Constructs, and Teachers' Perceptions of Constructivist-Oriented TPACK. *Journal of Educational Technology & Society*, 17(1), 185–196. <http://www.jstor.org/stable/jeductechsoci.17.1.185>
- Koh, J. H. L., Chai, C. S., & Lim, W. Y. (2017). Teacher Professional Development for TPACK-21CL: Effects on Teacher ICT Integration and Student Outcomes. *Journal of Educational Computing Research*, 55(2), 172–196. <https://doi.org/10.1177/0735633116656848>
- Koh, J. H. L., Chai, C. S., Benjamin, W., & Hong, H. Y. (2015). Technological Pedagogical Content Knowledge (TPACK) and Design Thinking: A Framework to Support ICT Lesson Design for 21st Century Learning. *Asia-Pacific Education Researcher*, 24(3), 535–543. <https://doi.org/10.1007/s40299-015-0237-2>
- Kuloğlu, A., & Karabekmez, V. (2022). The Relationship Between 21st-century Teacher Skills and Critical Thinking Skills of Classroom Teacher. In *International Journal of Psychology and Educational Studies* (Vol. 9, Issue 1, pp. 91–101).

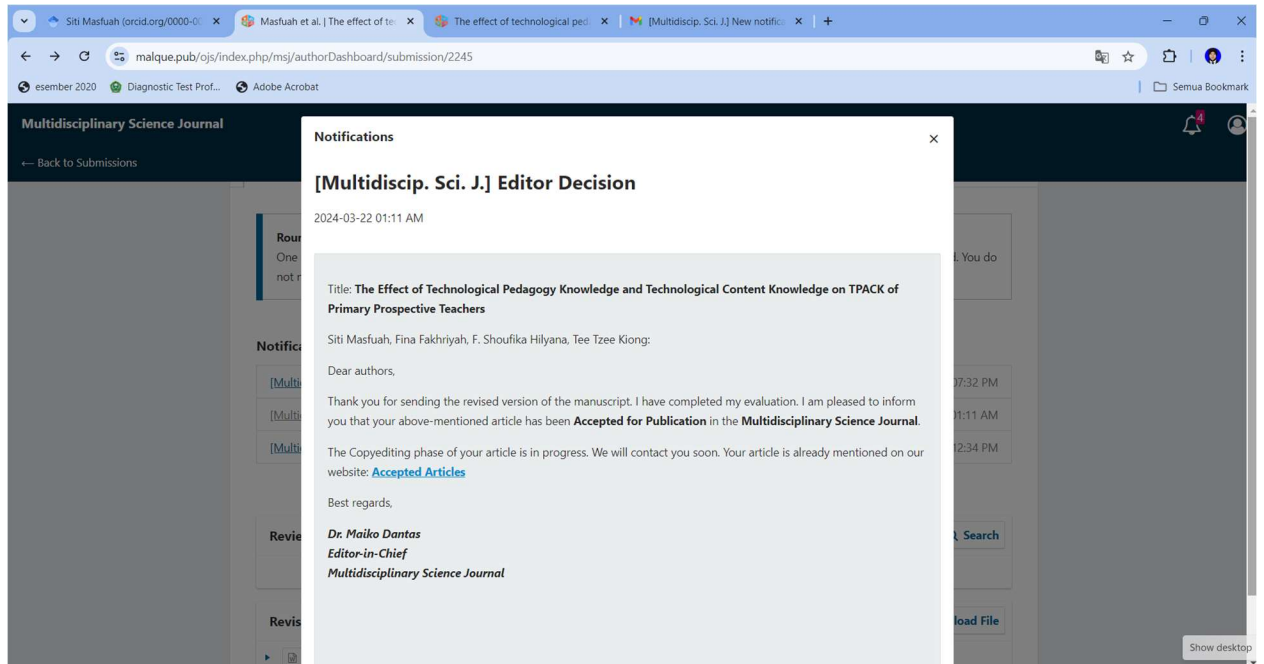
- <https://doi.org/10.52380/ijpes.2022.9.1.551>
- Kumari, K., & Yadav, S. (2018). Linear regression analysis study. *Journal of the Practice of Cardiovascular Sciences*, 4(1), 33. https://doi.org/10.4103/jpcs.jpcs_8_18
- Masfuah, S., & Fakhriyah, F. (2017). The Aspect of Science Literacy for Students of Elementary School Education Program Through the Application of Project Based Learning. *Unnes Science Education Journal*, 6(3), 1708–1716. <http://journal.unnes.ac.id/sju/index.php/usej%0ADEVELOPING>
- Messina, L., & Tabone, S. (2012). Integrating Technology into Instructional Practices Focusing on Teacher Knowledge. *Procedia - Social and Behavioral Sciences*, 46(2011), 1015–1027. <https://doi.org/10.1016/j.sbspro.2012.05.241>
- Munna, A. S., & Kalam, M. A. (2021). Teaching and learning process to enhance teaching effectiveness: literature review. *International Journal of Humanities and Innovation (IJHI)*, 4(1), 1–4. <https://doi.org/10.33750/ijhi.v4i1.102>
- OECD. (2020). Technical Report 2022. (2022).
- Okoye, K., Arrona-Palacios, A., Camacho-Zuñiga, C., Hammout, N., Nakamura, E. L., Escamilla, J., & Hosseini, S. (2020). Impact of students evaluation of teaching: a text analysis of the teachers qualities by gender. *International Journal of Educational Technology in Higher Education*, 17(1). <https://doi.org/10.1186/s41239-020-00224-z>
- Önen, Z., & Sincar, M. (2019). An analysis of teacher's performance evaluation at private schools: Kahramanmaraş and gaziantep sample. *Educational Administration: Theory and Practice*, 25(1), 169–190. <https://doi.org/10.14527/kuey.2019.005>
- Prahani, B. K., Amiruddin, M. Z., Suprpto, N., Deta, U. A., & Cheng, T. H. (2022). The trend of physics education research during COVID-19 pandemic. *International Journal of Educational Methodology*, 8(3), 517-533. <https://doi.org/10.12973/ijem.8.3.517>
- Rohandi, R. (2017). Teaching and Learning Science: Students' Perspective. *International Journal of Indonesian Education and Teaching*, October, 16–31. <https://doi.org/10.24071/ijiet.2017.010103>
- Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, 46(8), 909–921. <https://doi.org/10.1002/tea.20327>
- Sojanah, J., Suwatno, Kodri, & Machmud, A. (2021). Factors affecting teachers' technological pedagogical and content knowledge (A survey on economics teacher knowledge). *Cakrawala Pendidikan*, 40(1), 1–16. <https://doi.org/10.21831/cp.v40i1.31035>
- Suganda, H., Riandi, R., & Purwianingsih, W. (2021). TPACK perception analysis of teachers in facing 21st-century learning. *Jurnal Bioedukatika*, 9(2), 93. <https://doi.org/10.26555/bioedukatika.v9i2.17788>
- Susanti, N., Hadiyanto, & Mukminin, A. (2022). The Effects of TPACK Instrument Variables on Teacher Candidates in Higher Education. *Journal of Higher Education Theory and Practice*, 22(2). <https://doi.org/10.33423/jhetp.v22i2.5041>
- Tsekhmister, Y. (2022). Effectiveness of Practical Experiences in Using Digital Pedagogies in Higher Education: A Meta-Analysis. *Journal of Higher Education Theory and Practice*, 22(15), 138-150. <https://doi.org/10.33423/jhetp.v22i15.5567>
- Ucak, E. (2019). "Science teaching and science teachers" from students' point of view. *International Journal of Educational Methodology*, 5(2), 221-233. <https://doi.org/10.12973/ijem.5.2.221>
- Virtue, E., Maddox, G., & Pfaff, K. (2019). The Lasting Effects of Learning Communities. *Learning Communities Research and Practice*, 7(2), 6.
- Weinstein, Y., Madan, C. R., & Sumeracki, M. A. (2018). Teaching the science of learning. *Cognitive Research: Principles and Implications*, 3(1). <https://doi.org/10.1186/s41235-017-0087-y>
- Wismath, S. L., & Orr, D. (2015). The Canadian Journal for the Scholarship of Teaching and Learning Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning. *The Canadian Journal for the Scholarship of Teaching and Learning*, 6(3). http://ir.lib.uwo.ca/cjsotl_rcacea%5Cnhttp://ir.lib.uwo.ca/cjsotl_rcacea/vol6/iss3/10
- Wong, C. L., Chu, H. E., & Yap, K. C. (2020). A Framework for Defining Scientific Concepts in Science Education. *Asia-Pacific Science Education*, 6(2), 615–644. <https://doi.org/10.1163/23641177-bja10010>
- Young, J.R. (2016). Unpacking TPACK in Mathematics education research: A systematic review of meta-analyses. *International Journal of Educational Methodology*, 2(1), 19-29. <https://doi.org/10.12973/ijem.2.1.19>
- Afdal, H. W., & Spernes, K. (2018). Designing and redesigning research-based teacher education. *Teaching and Teacher Education*, 74, 215-228.
- Nagatsu, M., Davis, T., DesRoches, C. T., Koskinen, I., MacLeod, M., Stojanovic, M., & Thorén, H. (2020). Philosophy of science for sustainability science. *Sustainability Science*, 15, 1807-1817.

- 460 Wenglein, S., Bauer, J., Heininger, S., & Prenzel, M. (2015). Kompetenz angehender Lehrkräfte zum Argumentieren mit Evidenz:
461 Erhöht ein Training von Heuristiken die Argumentationsqualität. *Unterrichtswissenschaft*, 43(3), 209-224.

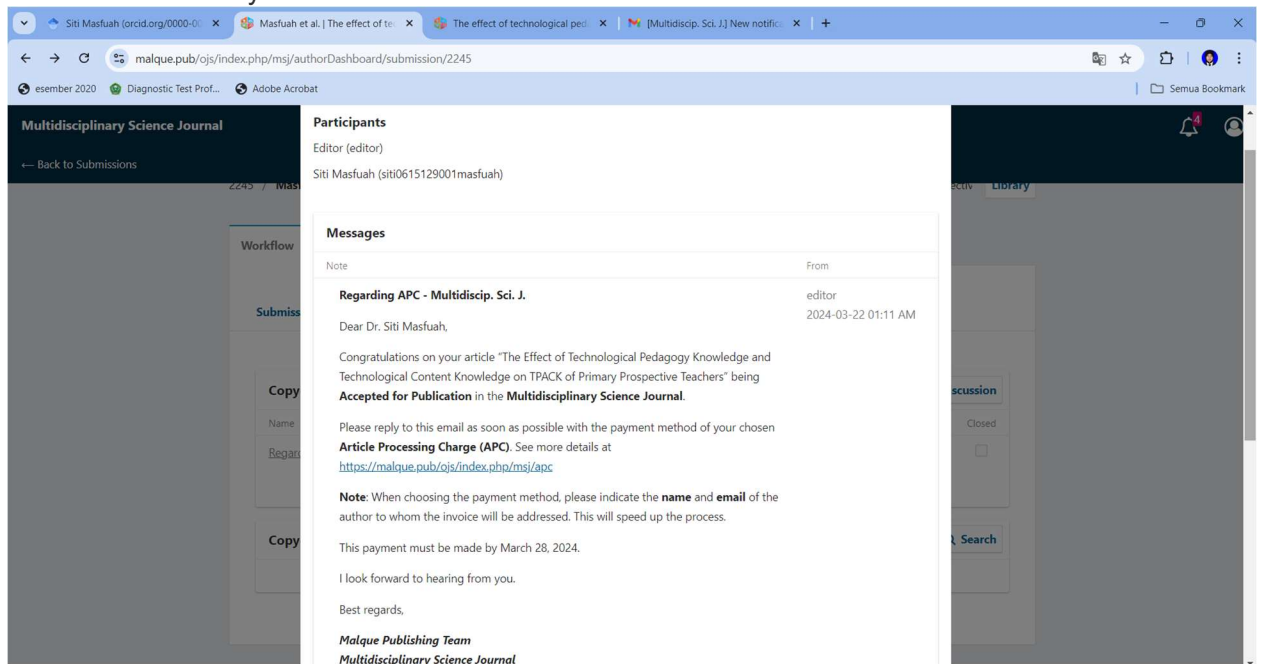
No	Comments	Action
1	<p>Reviewer A:</p> <p>However, the transition between discussing the general role of teachers and the specific focus on TPACK could be smoother.</p> <p>It would be beneficial to clearly outline the research gap or problem statement that necessitates the investigation of TPK and TCK's impact on TPACK.</p> <p>Additionally, incorporating more recent references to support the significance of TPACK in teacher training would enhance the introduction's relevance and currency.</p> <p>In the literature review, there is a lack of critical analysis and synthesis of existing literature on the subject. To strengthen this section, the authors could compare and contrast different studies that have explored the relationship between TPK, TCK, and TPACK.</p> <p>Including a conceptual framework or theoretical model that illustrates how these knowledge domains interact and influence each other would provide a clearer structure to the literature review.</p> <p>The conclusion succinctly summarizes the study's main findings but misses an opportunity to offer practical recommendations or suggestions for future research.</p> <p>Including actionable insights for teacher educators or policymakers based on the study's results would enhance the conclusion's significance.</p>	<p>TPACK equips teachers with the science knowledge and skills to integrate technology effectively into their teaching practices</p> <p>Already stated in the last paragraph of introduction.</p> <p>Already stated in the first paragraph of introduction.</p> <p>In the realm of educational technology, the concepts of Technological Pedagogical Knowledge, Technological Content Knowledge, and Technological Pedagogical Content Knowledge are interconnected (Koehler, 2014).</p> <p>Already explained in Figure 1.</p> <p>Already discussed in the Conclusions and Future.</p> <p>We added: 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.</p>

2	<p>Reviewer B:</p> <p>The methodology has a limited discussion on the rationale behind choosing specific data collection instruments or the sampling strategy employed. Providing a justification for the selection of instruments and participants would enhance the methodological rigor of the study.</p>	<p>I had include the citation for:</p> <p>The applied instruments were easy 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 (Shoufika Hilyana et al., 2023; Fakhriyah et al., 2022).ß</p>
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10. Pemberitahuan Artikel Accepted for Publication



11. Permintaan Pembayaran



The screenshot shows a web browser window with multiple tabs. The active tab is titled "malque.pub/ojs/index.php/msj/authorDashboard/submission/2245". The browser's address bar shows the URL. Below the browser window, there is a dark sidebar on the left with the text "Multidisciplinary Science Journal" and a link "Back to Submissions". The main content area is divided into two sections: "Participants" and "Messages".

Participants

Editor (editor)
Siti Masfiah (siti0615129001masfiah)

Messages

Note	From
<p>Regarding APC - Multidiscip. Sci. J.</p> <p>Dear Dr. Siti Masfiah,</p> <p>Congratulations on your article "The Effect of Technological Pedagogy Knowledge and Technological Content Knowledge on TPACK of Primary Prospective Teachers" being Accepted for Publication in the Multidisciplinary Science Journal.</p> <p>Please reply to this email as soon as possible with the payment method of your chosen Article Processing Charge (APC). See more details at https://malque.pub/ojs/index.php/msj/apc</p> <p>Note: When choosing the payment method, please indicate the name and email of the author to whom the invoice will be addressed. This will speed up the process.</p> <p>This payment must be made by March 28, 2024.</p> <p>I look forward to hearing from you.</p> <p>Best regards,</p> <p><i>Malque Publishing Team</i> <i>Multidisciplinary Science Journal</i></p>	<p>editor 2024-03-22 01:11 AM</p>

11. Perminataan Pembayaran

The screenshot shows a web browser window with multiple tabs open. The active tab is titled "Article Processing Charge" and the address bar shows the URL "malque.pub/ojs/index.php/msj/apc". The website header features the Malque Publishing logo and navigation links: "Publisher home", "About us", "siti0615129001masfiah", and social media icons for Twitter, Facebook, Instagram, and LinkedIn. Below the header, the main navigation bar includes "Home", "About", "Guidelines and Policies", "Articles", "Contact", and a yellow "SUBMIT YOUR PAPER" button. The main content area has a dark background with a DNA helix image and the title "Article Processing Charge (APC)".

Article Processing Charge (APC)

The Multidisciplinary Science Journal (ISSN 2675-1240) publishes all articles with full open access. To provide this free access to readers and cover the costs associated with copyediting, typesetting, long-term archiving (DOI), and journal management, an **Article Processing Charge (APC)** of 500 USD (American Dollars) is required for papers accepted after peer review, to be paid by the authors or their institutions.

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12. Pembayaran Artikel

The screenshot shows a web browser window with multiple tabs. The active tab is titled "malque.pub/ojs/index.php/msj/authorDashboard/submission/2245#workflow". The browser's address bar shows the URL. The page content is the author dashboard for the "Multidisciplinary Science Journal". On the left, there is a sidebar with a "Back to Submissions" link and a list of submission statuses: "Workflow", "Submitted", "Copy", "Name", "Regard", and "Copy". The main content area displays two email messages from the "Malque Publishing Team".

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This payment must be made by March 28, 2024.

I look forward to hearing from you.

Best regards,

Malque Publishing Team
Multidisciplinary Science Journal

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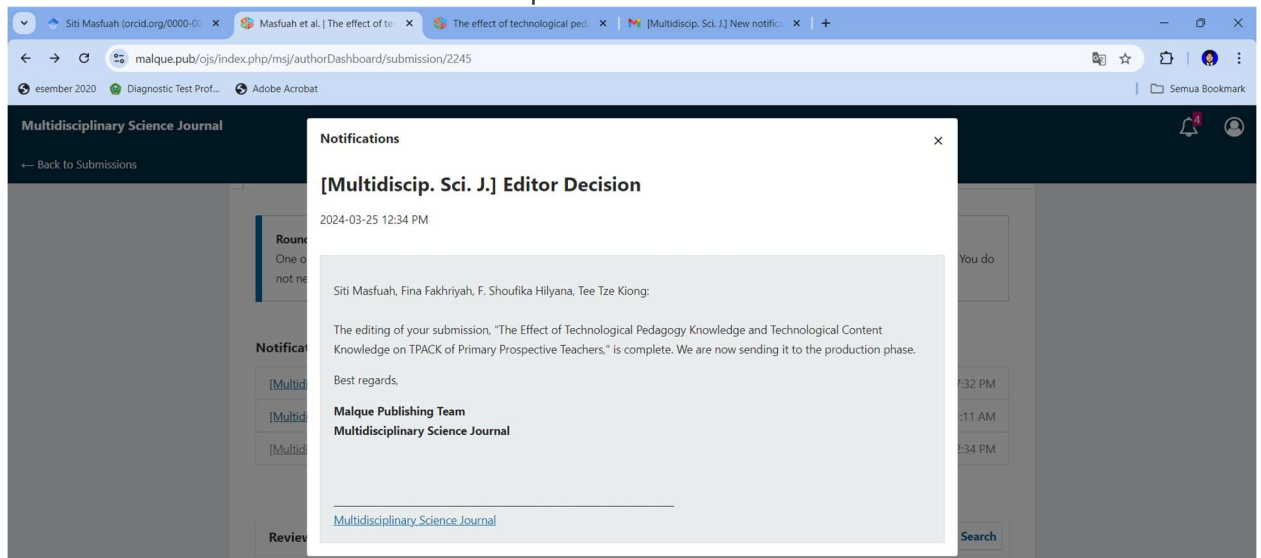
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13. Pemberitahuan bahwa Artikel Masuk Tahap Produksi



14. Permohonan Proof reading dan Perbaikan Artikel

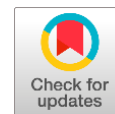
The screenshot shows a web browser with multiple tabs open. The active tab is titled "malque.pub/ojs/index.php/msj/authorDashboard/submission/2245#workflow". The browser's address bar shows the URL. The page content is a dark-themed interface for the "Multidisciplinary Science Journal". A modal window titled "Proof Reading [MultiScience-2024188]" is open, displaying a message from the editor.

Proof Reading [MultiScience-2024188]

Participants
Editor (editor)
Thibério de Souza Castelo (tcastelo1)
Siti Masfiah (siti0615129001masfiah)

Messages

Note	From
Dear Dr. Masfiah, The publication of your article in the Multidisciplinary Science Journal is very close. So we're entering the <i>Proof Reading</i> phase. The <i>Uncorrected Proof</i> is attached. Please note the comments below: 1. Read the entire article carefully to correct possible typos in all sections. 2. "Keywords" should not be sentences, and not exceed six words, should not be included in the title, so other words should replace some of them. 3. Please make sure to highlight in yellow or other color of your preference any changes made to the text so that we know and can make the changes to the final file. Please resend the article by April 22, 2024 . Best regards, Malque Publishing Team www.malque.pub e2024188.pdf	tcastelo1 2024-04-17 01:36 PM



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

Siti Masfuah^a   | Fina Fakhriyah^a  | F. Shoufika Hilyana^a  | Tee Tze Kiong^b 

^aUniversitas Muria Kudus, Indonesia.

^bUniversiti Tun Hussein Onn Malaysia, Malaysia.

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 $Y = 1.752 + 0.452X_1 + 0.524X_2$. 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: technological pedagogy content knowledge, technological pedagogy knowledge, TPACK, primary prospective teacher, 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 development of teacher and student experiences in learning is 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) from 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 skills 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 prospective primary school teacher students 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. The students 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 students.

Many studies attempted to improve the TPACK ability of teachers and prospective teachers. For example, Fakhriyah et al. (2017) found 33.8% of students had a functional level while 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) explained that looking for relationships 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 realm 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 prospective teacher students.

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).

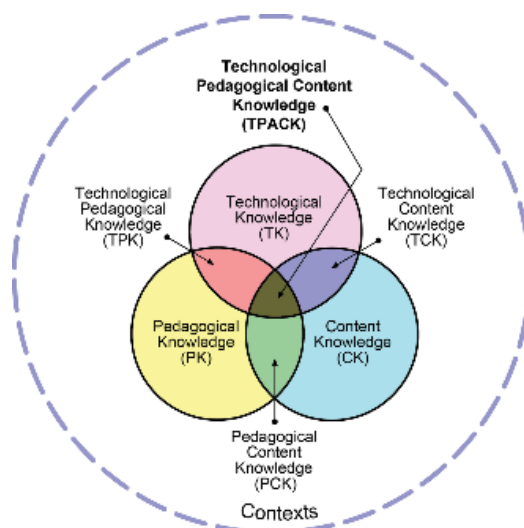


Figure 1 TPACK Framework.

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 convey the knowledge and substance to 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 easy 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

3.2. 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 prospective primary school teachers 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 indicates the rejection toward 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 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 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.

Ho₁: TPK has no significant effect on TPACK.

Ha₁: TPK simultaneously has a significant effect on TPACK.

Ho₂: TCK has no significant effect on TPACK.

Ha₂: TCK simultaneously has a significant effect on TPACK.

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.

The Table 5 shows the ability of TPK and TCK for each student is different. Figure 2 and Figure 3 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

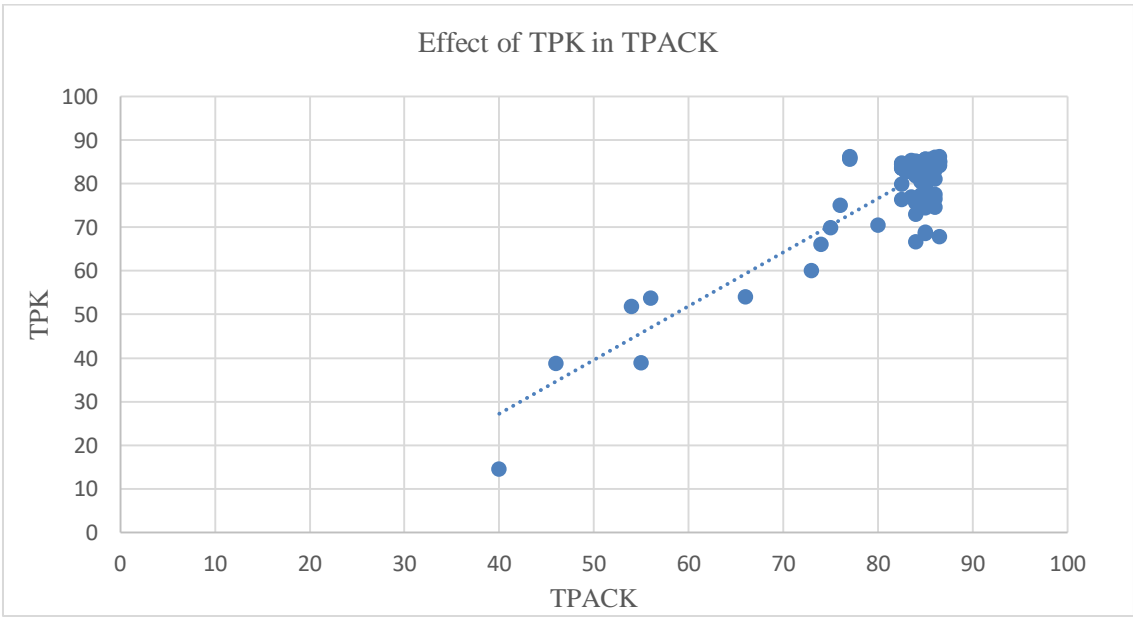


Figure 2 Effect Of TPK in TPACK.

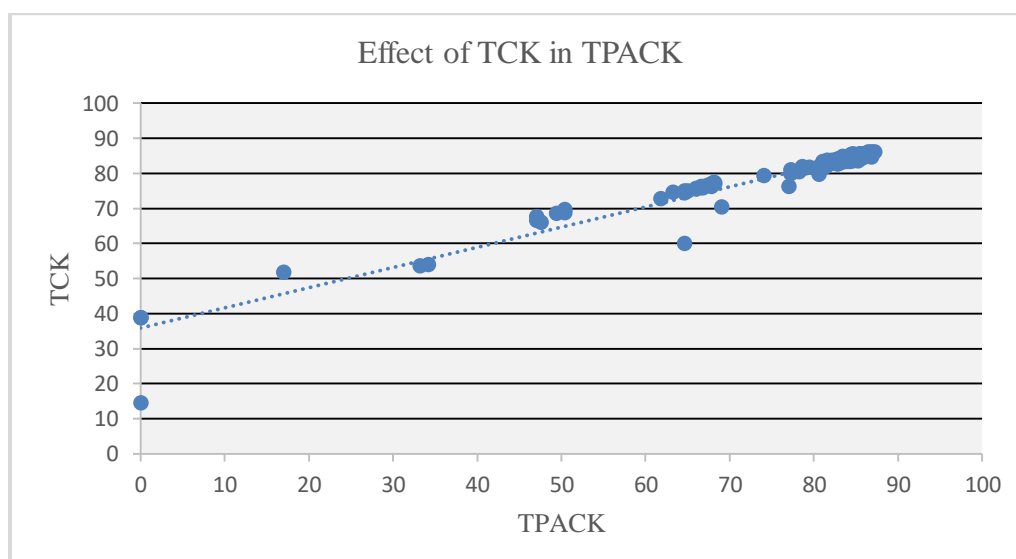


Figure 3 Effect of TPK in TPACK.

4. Discussion

Teachers must be literate to apply various devices and media for learning. This matter covers 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 $Y = 1.752 + 0.452X_1 + 0.524X_2$. 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 lead to high TPACK competency. 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. In this case, the teacher adapted 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 prospective teacher students 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 prospective teacher students 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 prospective teacher students to teach the primary school students. These primary school students think concretely so that the prospective teacher students must master the fundamental concepts. The natural feature of science is to understand the nature and the world. Thus, the prospective teacher students 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 prospective teacher students 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 is concerned with student-centered teaching (Shah & Sanothimi, 2021). Mastery of student characteristics requires more skills for prospective students. Therefore, prospective teacher students 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 dealt with lesson designs, lesson plans, and teaching simulations. Before teaching, the prospective teacher students 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 provided opportunities for students to connect theoretical concepts with everyday life and to create innovative learning programs (Granjeiro, 2019). This competency deals with the material delivered to students. The materials applied innovative learning media, concrete material, examples of equipment, and daily activities related to the science material being studied. 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 prospective teachers attempted to learn to be excellent teachers. Thus, they did not understand students in more detail. The prospective teachers 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, interleaving practicum, elaboration, and dual coding (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 provided 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 mix 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 concrete material examples based on daily life, 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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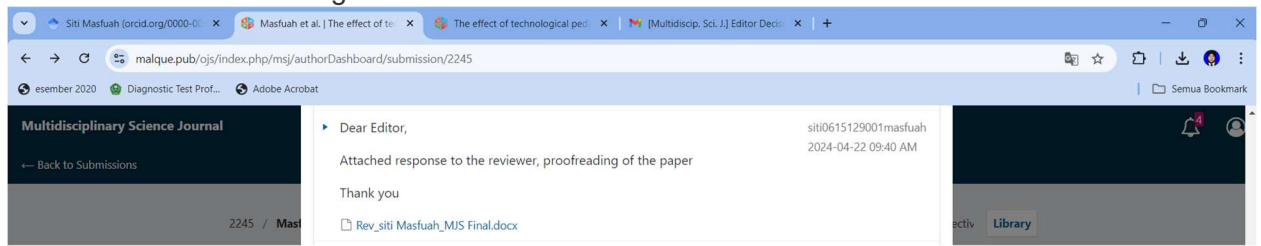
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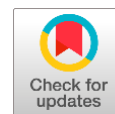
References

- Abdullateef, S., T. (2021). Remote Learning: Fostering Learning of 21st Century Skills through Digital Learning Tools. *Arab World English Journal*, 7(1), 190–201. <https://doi.org/10.24093/awej/call7.14>
- Albeta, S. W., Firdaus, L. N., Copriady, J., & Alimin, M. (2023). TPACK-based blended learning as an implementation of progressivism education: A systematic literature review. *Jurnal Pendidikan Vokasi*, 13(1), 44–59. <https://doi.org/10.21831/jpv.v13i1.51287>
- Alcivar, Carmen Magdalena Mero, Tatiana Lizeth Ibarra Quimi, M. F. Z. B. c. (2020). The motivation and its importance in the teaching-learning process. *International Research Journal of Management, IT and Social Sciences*, 7(1), 138–144. <https://doi.org/10.21744/irjmis.v7n1.832>
- Almonacid-Fierro, A. (2023). International Journal of Educational Methodology Analysis of Pedagogical Content Knowledge in Science Teacher Education: A Systematic Review 2011-2021. 9(3), 525–534.
- Antinluoma, M., Ilomaki, L., Lahti-Nuuttila, P., & Toom, A. (2018). Schools as Professional Learning Communities. *Journal of Education and Learning*, 7(5), 76. <https://doi.org/10.5539/jel.v7n5p76>
- Anud, Edgar and Caro, V. (2022). Teaching Performance of Science Teachers in the New Normal and Their Technological Pedagogical and Content Knowledge (Tpack) Self-Efficacy. *International Journal of Applied Science and Research*, 5(4), 81–84. <https://doi.org/10.56293/ijasr.2022.5410>
- Arnold, J., & Mundy, B. (2020). Praxis pedagogy in teacher education. *Smart Learning Environments*, 7(1). <https://doi.org/10.1186/s40561-020-0116-z>
- Aydede, M. N. (2022). Examining the Primary School Teacher Candidates' Science Learning Skills in Terms of Their Attitudes towards Science and Their Science Teaching Self-Efficacy Beliefs. *International Journal of Educational Methodology*, 8(4), 853–864. <https://doi.org/10.12973/ijem.8.4.853>
- Cabrera, L., Ketelhut, D. J., Mills, K., Killen, H., Coenraad, M., Byrne, V. L., Plane, J. D. (2023). Designing a Framework for Teachers' Integration of Computational Thinking into Elementary Science. *Journal of Research in Science Teaching in Science Education*, June, 1-36. <https://doi.org/10.1002/tea.21888>
- Cakir, M. (2008). Constructivist approaches to learning in science and their implication for science pedagogy: A literature review. *International Journal of Environmental and Science Education*, 3(4), 193–206.
- Creswell, J. W., & Creswell, J. D. (2018). Mixed Methods Procedures. In *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*.
- Doğan, S., & Julian, D. (2021). Collaborative Community Problem Solving: A Model and Recommendations to Support Community Practice. *Ahi Evran Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 7(1), 1–14. <https://doi.org/10.31592/aeusbed.676547>
- Fakhriyah, F., Masfuah, S., Hilyana, F. S., & Mamat, N. (2022). Analysis of Technological Pedagogical Content Knowledge (Tpack) Ability Based on Science Literacy for Pre-Service Primary School Teachers in Learning Science Concepts. *Jurnal Pendidikan IPA Indonesia*, 11(3), 399–411. <https://doi.org/10.15294/jpii.v11i3.37305>
- Fakhriyah, F., Masfuah, S., Roysa, M., Rusilowati, A., & Rahayu, E. S. (2017). Student's science literacy in the aspect of content science? *Jurnal Pendidikan IPA Indonesia*, 6(1), 81–87. <https://doi.org/10.15294/jpii.v6i1.7245>
- Fariyani, Q., Mubarak, F. K., Masfu'ah, S., & Syukur, F. (2020). Pedagogical Content Knowledge of Pre-service Physics Teachers. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 9(1), 99–107. <https://doi.org/10.24042/jipfalbiruni.v9i1.3409>
- Fitzgerald, A., & Smith, K. (2016). Science that matters: Exploring science learning and teaching in primary schools. *Australian Journal of Teacher Education*, 41(4), 64–78. <https://doi.org/10.14221/ajte.2016v41n4.4>
- Garraway-Lashley, Y. M. (2019). Teaching Science at the Primary school Level: "Problems Teachers' are facing". *Asian Journal of Education and E-Learning*, 7(3), 81–94. <https://doi.org/10.24203/ajeel.v7i3.5847>
- Gopo, C. (2022). The Role of Technology in the Architecture of the 21st Century. The Official Research Journal of Tagum City Division.
- Granjeiro, É. M. (2019). Research-based teaching-learning method: A strategy to motivate and engage students in human physiology classes. *Advances in Physiology Education*, 43(4), 553–556. <https://doi.org/10.1152/advan.00034.2019>
- Hair, J. F., Ringle, C. M., & Sarstedt, M. (2013). Partial Least Squares Structural Equation Modeling: Rigorous Applications, Better Results and Higher Acceptance. *Long Range Planning*, 46(1–2), 1–12. <https://doi.org/10.1016/j.lrp.2013.01.001>
- Helaluddin, Fitriyay, D., Rante, S. V. N., Tulak, H., Ulfah, M., St., & Wijaya, H. (2023). Gen Z students perception of ideal learning in post-pandemic: A phenomenological study from Indonesia. *International Journal of Educational Methodology*, 9(2), 423-434. <https://doi.org/10.12973/ijem.9.2.423>
- Hilyana, F. S., Fakhriyah, F., & Masfuah, S. (2023, June). Analysis on the ability of primary teacher education lecturers in TPACK-based E-learning. In AIP Conference Proceedings (Vol. 2614, No. 1). AIP Publishing.
- Jan, H., (2017). Teacher of 21st Century: Characteristics and Development. *Research on Humanities and Social Sciences*, 7(9), 2225–0484. www.iiste.org
- Joo, Y. J., Park, S., & Lim, E. (2018). Factors Influencing Preservice Teachers' Intention to Use Technology: TPACK, Teacher Self-efficacy, and Technology Acceptance Model. *Journal of Educational Technology & Society*, 21(3), 48–59. <http://www.jstor.org/stable/26458506>
- Koehler, M. J., Mishra, P., Kereluik, K., Shin, T. S., & Graham, C. R. (2014). The technological pedagogical content knowledge framework. *Handbook of research on educational communications and technology*, 101-111.
- Kereluik, K., Mishra, P., Fahnoe, C., & Terry, L. (2013). What Knowledge Is of Most Worth. *Journal of Digital Learning in Teacher Education*, 29(4), 127–140. <https://doi.org/10.1080/21532974.2013.10784716>
- Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content (TPACK)? *Journal of Education*, 193(3), 13-19. <https://www.researchgate.net/publication/260281100>
- Koehler, M.J. and Mishra, P. (2008) 'Introducing TPCK. AACTE Committee on Innovation and Technology (Ed.): The Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators, pp.3–29, Lawrence Erlbaum Associates, Mahwah, NJ.
- Koh J. H. L, Ching Sing Chai, & Ching-Chung Tsai. (2014). Demographic Factors, TPACK Constructs, and Teachers' Perceptions of Constructivist-Oriented TPACK. *Journal of Educational Technology & Society*, 17(1), 185–196. <http://www.jstor.org/stable/jeductechsoci.17.1.185>
- Koh, J. H. L., Chai, C. S., & Lim, W. Y. (2017). Teacher Professional Development for TPACK-21CL: Effects on Teacher ICT Integration and Student Outcomes.

- Journal of Educational Computing Research*, 55(2), 172–196. <https://doi.org/10.1177/0735633116656848>
- Koh, J. H. L., Chai, C. S., Benjamin, W., & Hong, H. Y. (2015). Technological Pedagogical Content Knowledge (TPACK) and Design Thinking: A Framework to Support ICT Lesson Design for 21st Century Learning. *Asia-Pacific Education Researcher*, 24(3), 535–543. <https://doi.org/10.1007/s40299-015-0237-2>
- Kuloğlu, A., & Karabekmez, V. (2022). The Relationship Between 21st-century Teacher Skills and Critical Thinking Skills of Classroom Teacher. *In International Journal of Psychology and Educational Studies*, 9(1), 91–101. <https://doi.org/10.52380/ijpes.2022.9.1.551>
- Kumari, K., & Yadav, S. (2018). Linear regression analysis study. *Journal of the Practice of Cardiovascular Sciences*, 4(1), 33. https://doi.org/10.4103/jpcs.jpcs_8_18
- Masfuah, S., & Fakhriyah, F. (2017). The Aspect of Science Literacy for Students of Elementary School Education Program Through the Application of Project Based Learning. *Unnes Science Education Journal*, 6(3), 1708–1716. <http://journal.unnes.ac.id/sju/index.php/usej%0ADEVELOPING>
- Messina, L., & Tabone, S. (2012). Integrating Technology into Instructional Practices Focusing on Teacher Knowledge. *Procedia - Social and Behavioral Sciences*, 46(2011), 1015–1027. <https://doi.org/10.1016/j.sbspro.2012.05.241>
- Munna, A. S., & Kalam, M. A. (2021). Teaching and learning process to enhance teaching effectiveness: literature review. *International Journal of Humanities and Innovation (IJHI)*, 4(1), 1–4. <https://doi.org/10.33750/ijhi.v4i1.102>
- OECD. (2020). Technical Report 2022. (2022).
- Okoye, K., Arrona-Palacios, A., Camacho-Zuñiga, C., Hammout, N., Nakamura, E. L., Escamilla, J., & Hosseini, S. (2020). Impact of students evaluation of teaching: a text analysis of the teachers qualities by gender. *International Journal of Educational Technology in Higher Education*, 17(1). <https://doi.org/10.1186/s41239-020-00224-z>
- Önen, Z., & Sincar, M. (2019). An analysis of teacher's performance evaluation at private schools: Kahramanmaraş and gaziantep sample. *Educational Administration: Theory and Practice*, 25(1), 169–190. <https://doi.org/10.14527/kuey.2019.005>
- Prahani, B. K., Amiruddin, M. Z., Suprpto, N., Deta, U. A., & Cheng, T. H. (2022). The trend of physics education research during COVID-19 pandemic. *International Journal of Educational Methodology*, 8(3), 517-533. <https://doi.org/10.12973/ijem.8.3.517>
- Rohandi, R. (2017). Teaching and Learning Science: Students' Perspective. *International Journal of Indonesian Education and Teaching*, October, 16–31. <https://doi.org/10.24071/ijiet.2017.010103>
- Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, 46(8), 909–921. <https://doi.org/10.1002/tea.20327>
- Sojanah, J., Suwatno, Kodri, & Machmud, A. (2021). Factors affecting teachers' technological pedagogical and content knowledge (A survey on economics teacher knowledge). *Cakrawala Pendidikan*, 40(1), 1–16. <https://doi.org/10.21831/cp.v40i1.31035>
- Suganda, H., Riandi, R., & Purwianingsih, W. (2021). TPACK perception analysis of teachers in facing 21st-century learning. *Jurnal Bioedukatika*, 9(2), 93. <https://doi.org/10.26555/bioedukatika.v9i2.17788>
- Susanti, N., Hadiyanto, & Mukminin, A. (2022). The Effects of TPACK Instrument Variables on Teacher Candidates in Higher Education. *Journal of Higher Education Theory and Practice*, 22(2). <https://doi.org/10.33423/jhetp.v22i2.5041>
- Tsekhmister, Y. (2022). Effectiveness of Practical Experiences in Using Digital Pedagogies in Higher Education: A Meta-Analysis. *Journal of Higher Education Theory and Practice*, 22(15), 138-150. <https://doi.org/10.33423/jhetp.v22i15.5567>
- Ucak, E. (2019). "Science teaching and science teachers" from students' point of view. *International Journal of Educational Methodology*, 5(2), 221-233. <https://doi.org/10.12973/ijem.5.2.221>
- Virtue, E., Maddox, G., & Pfaff, K. (2019). The Lasting Effects of Learning Communities. *Learning Communities Research and Practice*, 7(2), 6.
- Weinstein, Y., Madan, C. R., & Sumeracki, M. A. (2018). Teaching the science of learning. *Cognitive Research: Principles and Implications*, 3(1). <https://doi.org/10.1186/s41235-017-0087-y>
- Wismath, S. L., & Orr, D. (2015). The Canadian Journal for the Scholarship of Teaching and Learning Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning. *The Canadian Journal for the Scholarship of Teaching and Learning*, 6(3). http://ir.lib.uwo.ca/cjsotl_rcacea%5Cnhttp://ir.lib.uwo.ca/cjsotl_rcacea/vol6/iss3/10
- Wong, C. L., Chu, H. E., & Yap, K. C. (2020). A Framework for Defining Scientific Concepts in Science Education. *Asia-Pacific Science Education*, 6(2), 615–644. <https://doi.org/10.1163/23641177-bja10010>
- Young, J.R. (2016). Unpacking TPACK in Mathematics education research: A systematic review of meta-analyses. *International Journal of Educational Methodology*, 2(1), 19-29. <https://doi.org/10.12973/ijem.2.1.19>
- Afdal, H. W., & Spernes, K. (2018). Designing and redesigning research-based teacher education. *Teaching and Teacher Education*, 74, 215-228.
- Nagatsu, M., Davis, T., DesRoches, C. T., Koskinen, I., MacLeod, M., Stojanovic, M., & Thorén, H. (2020). Philosophy of science for sustainability science. *Sustainability Science*, 15, 1807-1817.
- Wenglein, S., Bauer, J., Heininger, S., & Prenzel, M. (2015). Kompetenz angehender Lehrkräfte zum Argumentieren mit Evidenz: Erhöht ein Training von Heuristiken die Argumentationsqualität. *Unterrichtswissenschaft*, 43(3), 209-224.

15. Submit hasil Proof Reading dan Perbaikan Artikel





The Effect of Technological Pedagogy Knowledge and Technological Content Knowledge on TPACK of Primary School Teacher Candidates

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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 $Y = 1.752 + 0.452X_1 + 0.524X_2$. 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: Technological Pedagogy Content Knowledge, Technological Pedagogy Knowledge, TPACK, 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 use of technology in learning encouraged students to become independent learners and improve teacher learning. Therefore, teachers must devise a strategy for teaching science, including TPACK. Thus, TPACK provides teachers with the science knowledge and skills 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 important to develop the nation 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 that 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 teacher candidates.

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).

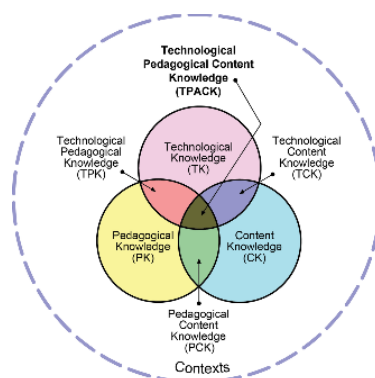


Figure 1 TPACK Framework

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 teacher candidates (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. 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 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.

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)

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

- Ho₁: TPK has no significant effect on TPACK.
- Ha₁: TPK simultaneously has a significant effect on TPACK.
- Ho₂: TCK has no significant effect on TPACK.
- Ha₂: TCK simultaneously has a significant effect on TPACK.

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 $Y = 1.752 + 0.452X_1 + 0.524X_2$.

From the analyses, the researchers concluded the correlation of the variables based on the R-square values. Table 5 shows the results.

Table 5 R Square

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

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.

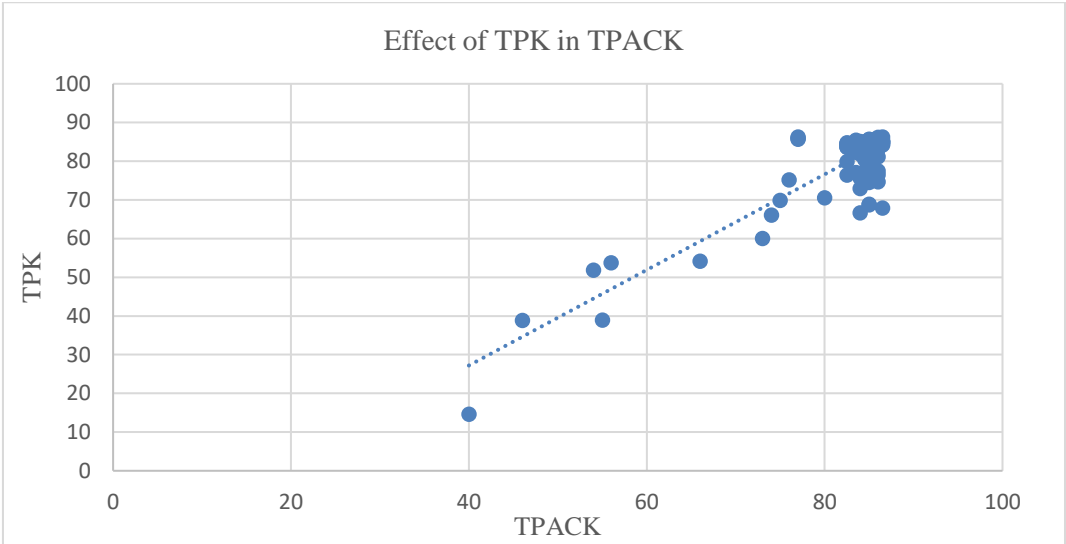


Figure 2 Effect Of TPK in TPACK

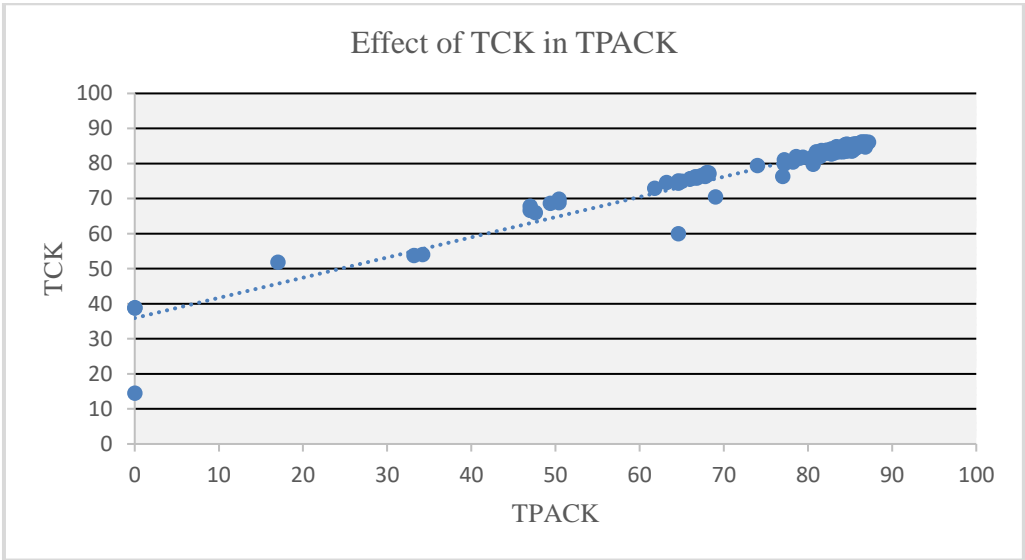


Figure 3 Effect of TPK in TPACK

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 TPACK 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 delivered 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 1 shows a linear correlation between TPK competence and TPACK while figure 2 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 deals 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, teacher candidates 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, an individual 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 teacher candidates (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 teacher candidates. In this research, the applied curriculum prepared the teacher candidates in teacher professional education. The teacher candidates 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 prepare 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 to 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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References

- Abdullateef, S., T. (2021). Remote Learning: Fostering Learning of 21st Century Skills through Digital Learning Tools. *Arab World English Journal*, 7(1), 190–201. <https://doi.org/10.24093/awej/call7.14>
- Albeta, S. W., Firdaus, L. N., Copriady, J., & Alimin, M. (2023). TPACK-based blended learning as an implementation of progressivism education: A systematic literature review. *Jurnal Pendidikan Vokasi*, 13(1), 44–59. <https://doi.org/10.21831/jpv.v13i1.51287>
- Alcivar, Carmen Magdalena Mero, Tatiana Lizeth Ibarra Quimi, M. F. Z. B. c. (2020). The motivation and its importance in the teaching-learning process. *International Research Journal of Management, IT and Social Sciences*, 7(1), 138–144. <https://doi.org/10.21744/irjmis.v7n1.832>
- Almonacid-Fierro, A. (2023). *International Journal of Educational Methodology Analysis of Pedagogical Content Knowledge in Science Teacher Education: A Systematic Review 2011-2021*. 9(3), 525–534.
- Antinluoma, M., Ilomaki, L., Lahti-Nuuttila, P., & Toom, A. (2018). Schools as Professional Learning Communities. *Journal of Education and Learning*, 7(5), 76. <https://doi.org/10.5539/jel.v7n5p76>
- Anud, Edgar and Caro, V. (2022). Teaching Performance of Science Teachers in the New Normal and Their Technological Pedagogical and Content Knowledge (Tpack) Self-Efficacy. *International Journal of Applied Science and Research*, 05(04), 81–84. <https://doi.org/10.56293/ijasr.2022.5410>
- Arnold, J., & Mundy, B. (2020). Praxis pedagogy in teacher education. *Smart Learning Environments*, 7(1). <https://doi.org/10.1186/s40561-020-0116-z>
- Aydede, M. N. (2022). Examining the Primary School Teacher Candidates' Science Learning Skills in Terms of Their Attitudes towards Science and Their Science Teaching Self-Efficacy Beliefs. *International Journal of Educational Methodology*, 8(4), 853–864. <https://doi.org/10.12973/ijem.8.4.853>
- Cabrera, L., Diane Jass Ketelhut, Kelly Mills, Heather Killen, Merijke Coenraad, Virginia L. Byrne, J. D. P. (2023). Designing a Framework for Teachers' Integration of Computational Thinking into Elementary Science. *Journal of Research in Science Teaching in Science Education*, June. <https://doi.org/10.1002/tea.21888>
- Cakir, M. (2008). Constructivist approaches to learning in science and their implication for science pedagogy: A literature review. *International Journal of Environmental and Science Education*, 3(4), 193–206.
- Creswell, J. W., & Creswell, J. D. (2018). Mixed Methods Procedures. In *Research Defign: Qualitative, Quantitative, and Mixed*

Methods Approaches.

- Doğan, S., & Julian, D. (2021). Collaborative Community Problem Solving: A Model and Recommendations to Support Community Practice. *Ahi Evran Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 7(1), 1–14. <https://doi.org/10.31592/aeusbed.676547>
- Fakhriyah, F., Masfuah, S., Hilyana, F. S., & Mamat, N. (2022). Analysis of Technological Pedagogical Content Knowledge (Tpack) Ability Based on Science Literacy for Pre-Service Primary School Teachers in Learning Science Concepts. *Jurnal Pendidikan IPA Indonesia*, 11(3), 399–411. <https://doi.org/10.15294/jpii.v11i3.37305>
- Fakhriyah, F., Masfuah, S., Roysa, M., Rusilowati, A., & Rahayu, E. S. (2017). Student's science literacy in the aspect of content science? *Jurnal Pendidikan IPA Indonesia*, 6(1), 81–87. <https://doi.org/10.15294/jpii.v6i1.7245>
- Fariyani, Q., Mubarak, F. K., Masfu'ah, S., & Syukur, F. (2020). Pedagogical Content Knowledge of Pre-service Physics Teachers. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 9(1), 99–107. <https://doi.org/10.24042/jipfalbiruni.v9i1.3409>
- Fitzgerald, A., & Smith, K. (2016). Science that matters: Exploring science learning and teaching in primary schools. *Australian Journal of Teacher Education*, 41(4), 64–78. <https://doi.org/10.14221/ajte.2016v41n4.4>
- Garraway-Lashley, Y. M. (2019). Teaching Science at the Primary school Level: "Problems Teachers' are facing". *Asian Journal of Education and E-Learning*, 7(3), 81–94. <https://doi.org/10.24203/ajeel.v7i3.5847>
- Gopo, C. (2022). The Role of Technology in the Architecture of the 21st Century. *The Official Research Journal of Tagum City Division*.
- Granjeiro, É. M. (2019). Research-based teaching-learning method: A strategy to motivate and engage students in human physiology classes. *Advances in Physiology Education*, 43(4), 553–556. <https://doi.org/10.1152/advan.00034.2019>
- Hair, J. F., Ringle, C. M., & Sarstedt, M. (2013). Partial Least Squares Structural Equation Modeling: Rigorous Applications, Better Results and Higher Acceptance. *Long Range Planning*, 46(1–2), 1–12. <https://doi.org/10.1016/j.lrp.2013.01.001>
- Helaluddin, Fitriyyah, D., Rante, S. V. N., Tulak, H., Ulfah, M., St., & Wijaya, H. (2023). Gen Z students perception of ideal learning in post-pandemic: A phenomenological study from Indonesia. *International Journal of Educational Methodology*, 9(2), 423–434. <https://doi.org/10.12973/ijem.9.2.423>
- Hilyana, F. S., Fakhriyah, F., & Masfuah, S. (2023, June). Analysis on the ability of primary teacher education lecturers in TPACK-based E-learning. In *AIP Conference Proceedings* (Vol. 2614, No. 1). AIP Publishing.
- Jan, H., (2017). Teacher of 21st Century: Characteristics and Development. *Research on Humanities and Social Sciences*, 7(9), 2225–0484. www.iiste.org
- Joo, Y. J., Park, S., & Lim, E. (2018). Factors Influencing Preservice Teachers' Intention to Use Technology: TPACK, Teacher Self-efficacy, and Technology Acceptance Model. *Journal of Educational Technology & Society*, 21(3), 48–59. <http://www.jstor.org/stable/26458506>
- Koehler, M. J., Mishra, P., Kereluik, K., Shin, T. S., & Graham, C. R. (2014). The technological pedagogical content knowledge framework. *Handbook of research on educational communications and technology*, 101–111.
- Kereluik, K., Mishra, P., Fahnoe, C., & Terry, L. (2013). What Knowledge Is of Most Worth. *Journal of Digital Learning in Teacher Education*, 29(4), 127–140. <https://doi.org/10.1080/21532974.2013.10784716>
- Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content (TPACK)? *Journal of Education*, 193(3): 13–19. <https://www.researchgate.net/publication/260281100>
- Koehler, M.J. and Mishra, P. (2008) 'Introducing TPCK. AACTE Committee on Innovation and Technology (Ed.): The Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators, pp.3–29, Lawrence Erlbaum Associates, Mahwah, NJ.
- Koh J. H. L, Ching Sing Chai, & Ching-Chung Tsai. (2014). Demographic Factors, TPACK Constructs, and Teachers' Perceptions of Constructivist-Oriented TPACK. *Journal of Educational Technology & Society*, 17(1), 185–196. <http://www.jstor.org/stable/jeductechsoci.17.1.185>
- Koh, J. H. L., Chai, C. S., & Lim, W. Y. (2017). Teacher Professional Development for TPACK-21CL: Effects on Teacher ICT Integration and Student Outcomes. *Journal of Educational Computing Research*, 55(2), 172–196. <https://doi.org/10.1177/0735633116656848>
- Koh, J. H. L., Chai, C. S., Benjamin, W., & Hong, H. Y. (2015). Technological Pedagogical Content Knowledge (TPACK) and Design Thinking: A Framework to Support ICT Lesson Design for 21st Century Learning. *Asia-Pacific Education Researcher*, 24(3), 535–543. <https://doi.org/10.1007/s40299-015-0237-2>
- Kuloğlu, A., & Karabekmez, V. (2022). The Relationship Between 21st-century Teacher Skills and Critical Thinking Skills of Classroom Teacher. In *International Journal of Psychology and Educational Studies* (Vol. 9, Issue 1, pp. 91–101).

<https://doi.org/10.52380/ijpes.2022.9.1.551>

Kumari, K., & Yadav, S. (2018). Linear regression analysis study. *Journal of the Practice of Cardiovascular Sciences*, 4(1), 33. https://doi.org/10.4103/jpcs.jpcs_8_18

Masfuah, S., & Fakhriyah, F. (2017). The Aspect of Science Literacy for Students of Elementary School Education Program Through the Application of Project Based Learning. *Unnes Science Education Journal*, 6(3), 1708–1716. <http://journal.unnes.ac.id/sju/index.php/usej%0ADEVELOPING>

Messina, L., & Tabone, S. (2012). Integrating Technology into Instructional Practices Focusing on Teacher Knowledge. *Procedia - Social and Behavioral Sciences*, 46(2011), 1015–1027. <https://doi.org/10.1016/j.sbspro.2012.05.241>

Munna, A. S., & Kalam, M. A. (2021). Teaching and learning process to enhance teaching effectiveness: literature review. *International Journal of Humanities and Innovation (IJHI)*, 4(1), 1–4. <https://doi.org/10.33750/ijhi.v4i1.102>

OECD. (2020). Technical Report 2022. (2022).

Okoye, K., Arrona-Palacios, A., Camacho-Zuñiga, C., Hammout, N., Nakamura, E. L., Escamilla, J., & Hosseini, S. (2020). Impact of students evaluation of teaching: a text analysis of the teachers qualities by gender. *International Journal of Educational Technology in Higher Education*, 17(1). <https://doi.org/10.1186/s41239-020-00224-z>

Önen, Z., & Sincar, M. (2019). An analysis of teacher's performance evaluation at private schools: Kahramanmaraş and gaziantep sample. *Educational Administration: Theory and Practice*, 25(1), 169–190. <https://doi.org/10.14527/kuey.2019.005>

Prahani, B. K., Amiruddin, M. Z., Suprpto, N., Deta, U. A., & Cheng, T. H. (2022). The trend of physics education research during COVID-19 pandemic. *International Journal of Educational Methodology*, 8(3), 517–533. <https://doi.org/10.12973/ijem.8.3.517>

Rohandi, R. (2017). Teaching and Learning Science: Students' Perspective. *International Journal of Indonesian Education and Teaching*, October, 16–31. <https://doi.org/10.24071/ijiet.2017.010103>

Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, 46(8), 909–921. <https://doi.org/10.1002/tea.20327>

Sojanah, J., Suwatno, Kodri, & Machmud, A. (2021). Factors affecting teachers' technological pedagogical and content knowledge (A survey on economics teacher knowledge). *Cakrawala Pendidikan*, 40(1), 1–16. <https://doi.org/10.21831/cp.v40i1.31035>

Suganda, H., Riandi, R., & Purwianingsih, W. (2021). TPACK perception analysis of teachers in facing 21st-century learning. *Jurnal Bioedukatika*, 9(2), 93. <https://doi.org/10.26555/bioedukatika.v9i2.17788>

Susanti, N., Hadiyanto, & Mukminin, A. (2022). The Effects of TPACK Instrument Variables on Teacher Candidates in Higher Education. *Journal of Higher Education Theory and Practice*, 22(2). <https://doi.org/10.33423/jhetp.v22i2.5041>

Tsekhmister, Y. (2022). Effectiveness of Practical Experiences in Using Digital Pedagogies in Higher Education: A Meta-Analysis. *Journal of Higher Education Theory and Practice*, 22(15), 138–150. <https://doi.org/10.33423/jhetp.v22i15.5567>

Ucak, E. (2019). "Science teaching and science teachers" from students' point of view. *International Journal of Educational Methodology*, 5(2), 221–233. <https://doi.org/10.12973/ijem.5.2.221>

Virtue, E., Maddox, G., & Pfaff, K. (2019). The Lasting Effects of Learning Communities. *Learning Communities Research and Practice*, 7(2), 6.

Weinstein, Y., Madan, C. R., & Sumeracki, M. A. (2018). Teaching the science of learning. *Cognitive Research: Principles and Implications*, 3(1). <https://doi.org/10.1186/s41235-017-0087-y>

Wismath, S. L., & Orr, D. (2015). The Canadian Journal for the Scholarship of Teaching and Learning Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning. *The Canadian Journal for the Scholarship of Teaching and Learning*, 6(3). http://ir.lib.uwo.ca/cjsotl_rcacea%5Cnhttp://ir.lib.uwo.ca/cjsotl_rcacea/vol6/iss3/10

Wong, C. L., Chu, H. E., & Yap, K. C. (2020). A Framework for Defining Scientific Concepts in Science Education. *Asia-Pacific Science Education*, 6(2), 615–644. <https://doi.org/10.1163/23641177-bja10010>

Young, J.R. (2016). Unpacking TPACK in Mathematics education research: A systematic review of meta-analyses. *International Journal of Educational Methodology*, 2(1), 19–29. <https://doi.org/10.12973/ijem.2.1.19>

Afdal, H. W., & Spernes, K. (2018). Designing and redesigning research-based teacher education. *Teaching and Teacher Education*, 74, 215–228.

Nagatsu, M., Davis, T., DesRoches, C. T., Koskinen, I., MacLeod, M., Stojanovic, M., & Thorén, H. (2020). Philosophy of science for sustainability science. *Sustainability Science*, 15, 1807–1817.

- 458 Wenglein, S., Bauer, J., Heininger, S., & Prenzel, M. (2015). Kompetenz angehender Lehrkräfte zum Argumentieren mit Evidenz:
459 Erhöht ein Training von Heuristiken die Argumentationsqualität. *Unterrichtswissenschaft*, 43(3), 209-224.

16. Pemberitahuan Perbaikan Keyword

The screenshot shows a web browser window with multiple tabs. The active tab is titled "malque.pub/ojs/index.php/msj/authorDashboard/submission/2245". The browser's address bar shows the URL. Below the browser window, there is a dark sidebar on the left with the text "Multidisciplinary Science Journal" and a link "Back to Submissions". The main content area displays an email notification. The email is from "siti0615129001masfiah" dated "2024-04-22 09:40 AM". The subject is "Dear Editor,". The body of the email contains the following text: "Attached response to the reviewer, proofreading of the paper", "Thank you", and a link to "Rev_siti Masfiah_MJS Final.docx". Below this, there is a section titled "Dear Dr. Masfiah," dated "2024-04-23 11:34 AM". The text in this section reads: "The indicated changes were made. We noticed that the requests in the 'key-words' section were not met, please do it. 'Keywords' should not be sentences, and not exceed six words, should not be included in the title, so other words should replace some of them. Best regards, Malque Publishing Team www.malque.pub". The right sidebar of the browser shows a "Library" section.

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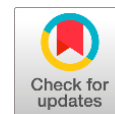
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The effect of technological pedagogy knowledge and technological content knowledge on TPACK of primary prospective teachers

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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 $Y = 1.752 + 0.452X_1 + 0.524X_2$. 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: technological pedagogy content knowledge, technological pedagogy knowledge, TPACK, primary prospective teacher, 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 development of teacher and student experiences in learning is 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) from 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 skills 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 prospective primary school teacher students 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. The students 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 students.

Many studies attempted to improve the TPACK ability of teachers and prospective teachers. For example, Fakhriyah et al. (2017) found 33.8% of students had a functional level while 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) explained that looking for relationships 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 realm 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 prospective teacher students.

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).

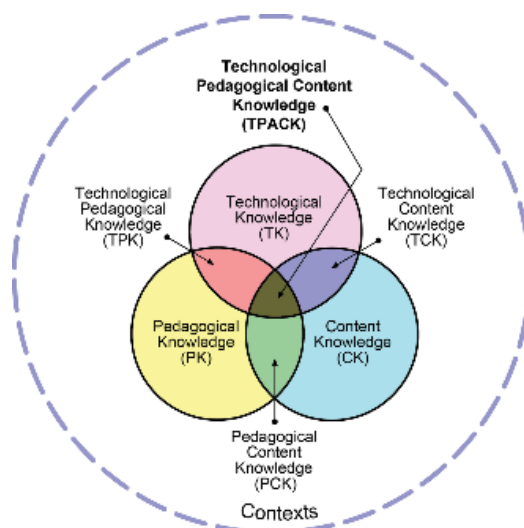


Figure 1 TPACK Framework.

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 convey the knowledge and substance to 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 easy 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

3.2. 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 prospective primary school teachers 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 indicates the rejection toward 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 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 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.

- Ho₁: TPK has no significant effect on TPACK.
- Ha₁: TPK simultaneously has a significant effect on TPACK.
- Ho₂: TCK has no significant effect on TPACK.
- Ha₂: TCK simultaneously has a significant effect on TPACK.

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 $Y = 1.752 + 0.452X_1 + 0.524X_2$.

From the analyses, the researchers concluded the correlation of the variables based on the R-square values. Table 5 shows the results.

The Table 5 shows the ability of TPK and TCK for each student is different. Figure 2 and Figure 3 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

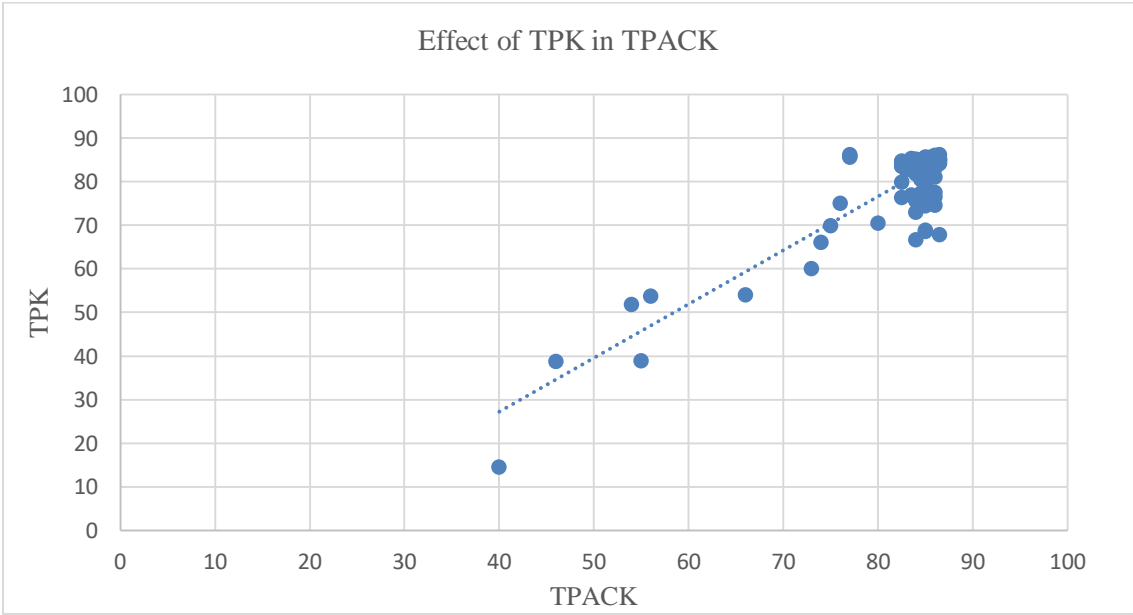


Figure 2 Effect Of TPK in TPACK.

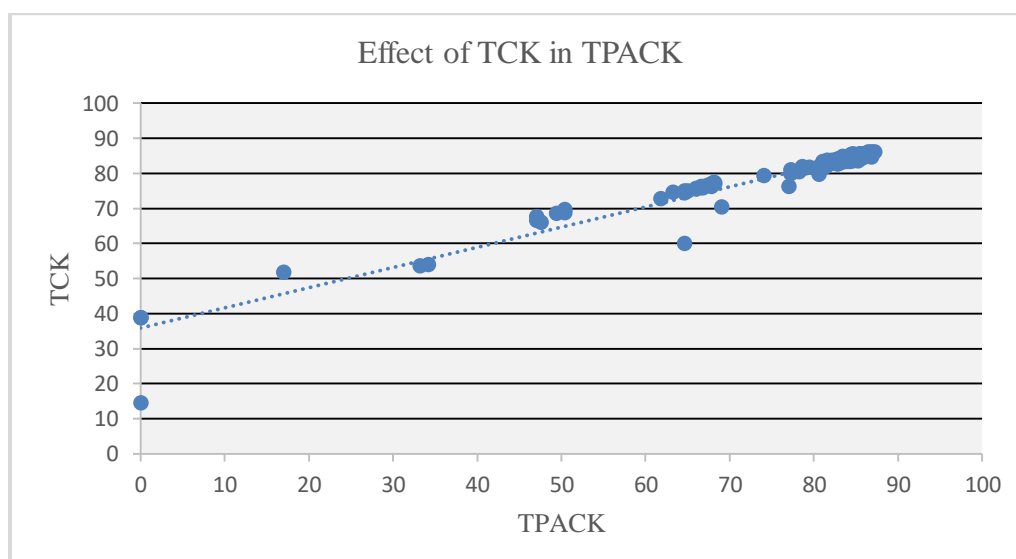


Figure 3 Effect of TPK in TPACK.

4. Discussion

Teachers must be literate to apply various devices and media for learning. This matter covers 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 $Y = 1.752 + 0.452X_1 + 0.524X_2$. 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 lead to high TPACK competency. 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. In this case, the teacher adapted 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 prospective teacher students 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 prospective teacher students 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 prospective teacher students to teach the primary school students. These primary school students think concretely so that the prospective teacher students must master the fundamental concepts. The natural feature of science is to understand the nature and the world. Thus, the prospective teacher students 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 prospective teacher students 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 is concerned with student-centered teaching (Shah & Sanothimi, 2021). Mastery of student characteristics requires more skills for prospective students. Therefore, prospective teacher students 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 dealt with lesson designs, lesson plans, and teaching simulations. Before teaching, the prospective teacher students 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 provided opportunities for students to connect theoretical concepts with everyday life and to create innovative learning programs (Granjeiro, 2019). This competency deals with the material delivered to students. The materials applied innovative learning media, concrete material, examples of equipment, and daily activities related to the science material being studied. 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 prospective teachers attempted to learn to be excellent teachers. Thus, they did not understand students in more detail. The prospective teachers 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, interleaving practicum, elaboration, and dual coding (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 provided 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 mix 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 concrete material examples based on daily life, 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

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Conflict of Interest

There is no conflict of interest in this research.

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References

- Abdullateef, S., T. (2021). Remote Learning: Fostering Learning of 21st Century Skills through Digital Learning Tools. *Arab World English Journal*, 7(1), 190–201. <https://doi.org/10.24093/awej/call7.14>
- Albeta, S. W., Firdaus, L. N., Copriady, J., & Alimin, M. (2023). TPACK-based blended learning as an implementation of progressivism education: A systematic literature review. *Jurnal Pendidikan Vokasi*, 13(1), 44–59. <https://doi.org/10.21831/jpv.v13i1.51287>
- Alcivar, Carmen Magdalena Mero, Tatiana Lizeth Ibarra Quimi, M. F. Z. B. c. (2020). The motivation and its importance in the teaching-learning process. *International Research Journal of Management, IT and Social Sciences*, 7(1), 138–144. <https://doi.org/10.21744/irjmis.v7n1.832>
- Almonacid-Fierro, A. (2023). International Journal of Educational Methodology Analysis of Pedagogical Content Knowledge in Science Teacher Education: A Systematic Review 2011-2021. 9(3), 525–534.
- Antinluoma, M., Ilomaki, L., Lahti-Nuuttila, P., & Toom, A. (2018). Schools as Professional Learning Communities. *Journal of Education and Learning*, 7(5), 76. <https://doi.org/10.5539/jel.v7n5p76>
- Anud, Edgar and Caro, V. (2022). Teaching Performance of Science Teachers in the New Normal and Their Technological Pedagogical and Content Knowledge (Tpack) Self-Efficacy. *International Journal of Applied Science and Research*, 5(4), 81–84. <https://doi.org/10.56293/ijasr.2022.5410>
- Arnold, J., & Mundy, B. (2020). Praxis pedagogy in teacher education. *Smart Learning Environments*, 7(1). <https://doi.org/10.1186/s40561-020-0116-z>
- Aydede, M. N. (2022). Examining the Primary School Teacher Candidates' Science Learning Skills in Terms of Their Attitudes towards Science and Their Science Teaching Self-Efficacy Beliefs. *International Journal of Educational Methodology*, 8(4), 853–864. <https://doi.org/10.12973/ijem.8.4.853>
- Cabrera, L., Ketelhut, D. J., Mills, K., Killen, H., Coenraad, M., Byrne, V. L., Plane, J. D. (2023). Designing a Framework for Teachers' Integration of Computational Thinking into Elementary Science. *Journal of Research in Science Teaching in Science Education*, June, 1-36. <https://doi.org/10.1002/tea.21888>
- Cakir, M. (2008). Constructivist approaches to learning in science and their implication for science pedagogy: A literature review. *International Journal of Environmental and Science Education*, 3(4), 193–206.
- Creswell, J. W., & Creswell, J. D. (2018). Mixed Methods Procedures. In Research Defign: Qualitative, Quantitative, and Mixed M ethods Approaches.
- Doğan, S., & Julian, D. (2021). Collaborative Community Problem Solving: A Model and Recommendations to Support Community Practice. *Ahi Evran Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 7(1), 1–14. <https://doi.org/10.31592/aeusbed.676547>
- Fakhriyah, F., Masfuah, S., Hilyana, F. S., & Mamat, N. (2022). Analysis of Technological Pedagogical Content Knowledge (Tpack) Ability Based on Science Literacy for Pre-Service Primary School Teachers in Learning Science Concepts. *Jurnal Pendidikan IPA Indonesia*, 11(3), 399–411. <https://doi.org/10.15294/jpii.v11i3.37305>
- Fakhriyah, F., Masfuah, S., Roysa, M., Rusilowati, A., & Rahayu, E. S. (2017). Student's science literacy in the aspect of content science? *Jurnal Pendidikan IPA Indonesia*, 6(1), 81–87. <https://doi.org/10.15294/jpii.v6i1.7245>
- Fariyani, Q., Mubarak, F. K., Masfu'ah, S., & Syukur, F. (2020). Pedagogical Content Knowledge of Pre-service Physics Teachers. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 9(1), 99–107. <https://doi.org/10.24042/jipfalbiruni.v9i1.3409>
- Fitzgerald, A., & Smith, K. (2016). Science that matters: Exploring science learning and teaching in primary schools. *Australian Journal of Teacher Education*, 41(4), 64–78. <https://doi.org/10.14221/ajte.2016v41n4.4>
- Garraway-Lashley, Y. M. (2019). Teaching Science at the Primary school Level: "Problems Teachers' are facing". *Asian Journal of Education and E-Learning*, 7(3), 81–94. <https://doi.org/10.24203/ajeel.v7i3.5847>
- Gopo, C. (2022). The Role of Technology in the Architecture of the 21st Century. The Official Research Journal of Tagum City Division.
- Granjeiro, É. M. (2019). Research-based teaching-learning method: A strategy to motivate and engage students in human physiology classes. *Advances in Physiology Education*, 43(4), 553–556. <https://doi.org/10.1152/advan.00034.2019>
- Hair, J. F., Ringle, C. M., & Sarstedt, M. (2013). Partial Least Squares Structural Equation Modeling: Rigorous Applications, Better Results and Higher Acceptance. *Long Range Planning*, 46(1–2), 1–12. <https://doi.org/10.1016/j.lrp.2013.01.001>
- Helaluddin, Fitriyayh, D., Rante, S. V. N., Tulak, H., Ulfah, M., St., & Wijaya, H. (2023). Gen Z students perception of ideal learning in post-pandemic: A phenomenological study from Indonesia. *International Journal of Educational Methodology*, 9(2), 423-434. <https://doi.org/10.12973/ijem.9.2.423>
- Hilyana, F. S., Fakhriyah, F., & Masfuah, S. (2023, June). Analysis on the ability of primary teacher education lecturers in TPACK-based E-learning. In AIP Conference Proceedings (Vol. 2614, No. 1). AIP Publishing.
- Jan, H., (2017). Teacher of 21st Century: Characteristics and Development. *Research on Humanities and Social Sciences*, 7(9), 2225–0484. www.iiste.org
- Joo, Y. J., Park, S., & Lim, E. (2018). Factors Influencing Preservice Teachers' Intention to Use Technology: TPACK, Teacher Self-efficacy, and Technology Acceptance Model. *Journal of Educational Technology & Society*, 21(3), 48–59. <http://www.jstor.org/stable/26458506>
- Koehler, M. J., Mishra, P., Kereluik, K., Shin, T. S., & Graham, C. R. (2014). The technological pedagogical content knowledge framework. *Handbook of research on educational communications and technology*, 101-111.
- Kereluik, K., Mishra, P., Fahnoe, C., & Terry, L. (2013). What Knowledge Is of Most Worth. *Journal of Digital Learning in Teacher Education*, 29(4), 127–140. <https://doi.org/10.1080/21532974.2013.10784716>
- Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content (TPACK)? *Journal of Education*, 193(3), 13-19. <https://www.researchgate.net/publication/260281100>
- Koehler, M.J. and Mishra, P. (2008) 'Introducing TPCK. AACTE Committee on Innovation and Technology (Ed.): The Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators, pp.3–29, Lawrence Erlbaum Associates, Mahwah, NJ.
- Koh J. H. L, Ching Sing Chai, & Ching-Chung Tsai. (2014). Demographic Factors, TPACK Constructs, and Teachers' Perceptions of Constructivist-Oriented TPACK. *Journal of Educational Technology & Society*, 17(1), 185–196. <http://www.jstor.org/stable/jeductechsoci.17.1.185>
- Koh, J. H. L., Chai, C. S., & Lim, W. Y. (2017). Teacher Professional Development for TPACK-21CL: Effects on Teacher ICT Integration and Student Outcomes.

Journal of Educational Computing Research, 55(2), 172–196. <https://doi.org/10.1177/0735633116656848>

Koh, J. H. L., Chai, C. S., Benjamin, W., & Hong, H. Y. (2015). Technological Pedagogical Content Knowledge (TPACK) and Design Thinking: A Framework to Support ICT Lesson Design for 21st Century Learning. *Asia-Pacific Education Researcher*, 24(3), 535–543. <https://doi.org/10.1007/s40299-015-0237-2>

Kuloğlu, A., & Karabekmez, V. (2022). The Relationship Between 21st-century Teacher Skills and Critical Thinking Skills of Classroom Teacher. *In International Journal of Psychology and Educational Studies*, 9(1), 91–101. <https://doi.org/10.52380/ijpes.2022.9.1.551>

Kumari, K., & Yadav, S. (2018). Linear regression analysis study. *Journal of the Practice of Cardiovascular Sciences*, 4(1), 33. https://doi.org/10.4103/jpcs.jpcs_8_18

Masfuah, S., & Fakhriyah, F. (2017). The Aspect of Science Literacy for Students of Elementary School Education Program Through the Application of Project Based Learning. *Unnes Science Education Journal*, 6(3), 1708–1716. <http://journal.unnes.ac.id/sju/index.php/usej%0ADEVELOPING>

Messina, L., & Tabone, S. (2012). Integrating Technology into Instructional Practices Focusing on Teacher Knowledge. *Procedia - Social and Behavioral Sciences*, 46(2011), 1015–1027. <https://doi.org/10.1016/j.sbspro.2012.05.241>

Munna, A. S., & Kalam, M. A. (2021). Teaching and learning process to enhance teaching effectiveness: literature review. *International Journal of Humanities and Innovation (IJHI)*, 4(1), 1–4. <https://doi.org/10.33750/ijhi.v4i1.102>

OECD. (2020). Technical Report 2022. (2022).

Okoye, K., Arrona-Palacios, A., Camacho-Zuñiga, C., Hammout, N., Nakamura, E. L., Escamilla, J., & Hosseini, S. (2020). Impact of students evaluation of teaching: a text analysis of the teachers qualities by gender. *International Journal of Educational Technology in Higher Education*, 17(1). <https://doi.org/10.1186/s41239-020-00224-z>

Önen, Z., & Sincar, M. (2019). An analysis of teacher's performance evaluation at private schools: Kahramanmaraş and gaziantep sample. *Educational Administration: Theory and Practice*, 25(1), 169–190. <https://doi.org/10.14527/kuey.2019.005>

Prahani, B. K., Amiruddin, M. Z., Suprpto, N., Deta, U. A., & Cheng, T. H. (2022). The trend of physics education research during COVID-19 pandemic. *International Journal of Educational Methodology*, 8(3), 517-533. <https://doi.org/10.12973/ijem.8.3.517>

Rohandi, R. (2017). Teaching and Learning Science: Students' Perspective. *International Journal of Indonesian Education and Teaching*, October, 16–31. <https://doi.org/10.24071/ijiet.2017.010103>

Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, 46(8), 909–921. <https://doi.org/10.1002/tea.20327>

Sojanah, J., Suwatno, Kodri, & Machmud, A. (2021). Factors affecting teachers' technological pedagogical and content knowledge (A survey on economics teacher knowledge). *Cakrawala Pendidikan*, 40(1), 1–16. <https://doi.org/10.21831/cp.v40i1.31035>

Suganda, H., Riandi, R., & Purwianingsih, W. (2021). TPACK perception analysis of teachers in facing 21st-century learning. *Jurnal Bioedukatika*, 9(2), 93. <https://doi.org/10.26555/bioedukatika.v9i2.17788>

Susanti, N., Hadiyanto, & Mukminin, A. (2022). The Effects of TPACK Instrument Variables on Teacher Candidates in Higher Education. *Journal of Higher Education Theory and Practice*, 22(2). <https://doi.org/10.33423/jhetp.v22i2.5041>

Tsekhmister, Y. (2022). Effectiveness of Practical Experiences in Using Digital Pedagogies in Higher Education: A Meta-Analysis. *Journal of Higher Education Theory and Practice*, 22(15), 138-150. <https://doi.org/10.33423/jhetp.v22i15.5567>

Ucak, E. (2019). "Science teaching and science teachers" from students' point of view. *International Journal of Educational Methodology*, 5(2), 221-233. <https://doi.org/10.12973/ijem.5.2.221>

Virtue, E., Maddox, G., & Pfaff, K. (2019). The Lasting Effects of Learning Communities. *Learning Communities Research and Practice*, 7(2), 6.

Weinstein, Y., Madan, C. R., & Sumeracki, M. A. (2018). Teaching the science of learning. *Cognitive Research: Principles and Implications*, 3(1). <https://doi.org/10.1186/s41235-017-0087-y>

Wismath, S. L., & Orr, D. (2015). The Canadian Journal for the Scholarship of Teaching and Learning Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning. *The Canadian Journal for the Scholarship of Teaching and Learning*, 6(3). http://ir.lib.uwo.ca/cjsotl_rcacea%5Cnhttp://ir.lib.uwo.ca/cjsotl_rcacea/vol6/iss3/10

Wong, C. L., Chu, H. E., & Yap, K. C. (2020). A Framework for Defining Scientific Concepts in Science Education. *Asia-Pacific Science Education*, 6(2), 615–644. <https://doi.org/10.1163/23641177-bja10010>

Young, J.R. (2016). Unpacking TPACK in Mathematics education research: A systematic review of meta-analyses. *International Journal of Educational Methodology*, 2(1), 19-29. <https://doi.org/10.12973/ijem.2.1.19>

Afdal, H. W., & Spernes, K. (2018). Designing and redesigning research-based teacher education. *Teaching and Teacher Education*, 74, 215-228.

Nagatsu, M., Davis, T., DesRoches, C. T., Koskinen, I., MacLeod, M., Stojanovic, M., & Thorén, H. (2020). Philosophy of science for sustainability science. *Sustainability Science*, 15, 1807-1817.

Wenglein, S., Bauer, J., Heininger, S., & Prenzel, M. (2015). Kompetenz angehender Lehrkräfte zum Argumentieren mit Evidenz: Erhöht ein Training von Heuristiken die Argumentationsqualität. *Unterrichtswissenschaft*, 43(3), 209-224.

17. Revisi Perbaikan Keywords

The screenshot shows a web browser window with multiple tabs. The active tab is 'malque.pub/ojs/index.php/msj/authorDashboard/submission/2245'. The browser's address bar and tabs are visible at the top. The main content area displays a message thread for submission 2245. The thread starts with a message from 'tcastelo1' dated '2024-04-23 11:34 AM'. The message text is: 'Attached response to the reviewer, proofreading of the paper. Thank you. [Rev_siti Masfuah_MJS Final.docx] Dear Dr. Masfuah, The indicated changes were made. We noticed that the requests in the "key-words" section were not met, please do it. "Keywords" should not be sentences, and not exceed six words, should not be included in the title, so other words should replace some of them. Best regards, Malque Publishing Team www.malque.pub'. Below this is a response from 'siti0615129001masfuah' dated '2024-04-23 01:41 PM'. The response text is: 'Dear Editor, Thanks for the correction. Attached is my keyword revision. Please correct it. Thank you. [Siti Masfuah_MJS Rev Keyword.docx]'. At the bottom of the message box is an 'Add Message' button. The background of the dashboard is dark grey with various navigation links like 'Workflow', 'Submission', 'Production', 'Discussion', and 'Library' visible on the right side.

Attached response to the reviewer, proofreading of the paper

Thank you

[Rev_siti Masfuah_MJS Final.docx]

Dear Dr. Masfuah,

tcastelo1
2024-04-23 11:34 AM

The indicated changes were made.

We noticed that the requests in the "key-words" section were not met, please do it.

"Keywords" should not be sentences, and not exceed six words, should not be included in the title, so other words should replace some of them.

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Dear Editor,

siti0615129001masfuah
2024-04-23 01:41 PM

Thanks for the correction

Attached is my keyword revision

Please correct it. Thank you

[Siti Masfuah_MJS Rev Keyword.docx]

Add Message



The Effect of Technological Pedagogy Knowledge and Technological Content Knowledge on TPACK of Primary School Teacher Candidates

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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 $Y = 1.752 + 0.452X_1 + 0.524X_2$. 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 use of technology in learning encouraged students to become independent learners and improve teacher learning. Therefore, teachers must devise a strategy for teaching science, including TPACK. Thus, TPACK provides teachers with the science knowledge and skills 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 important to develop the nation 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 that 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 **teacher candidates**.

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).

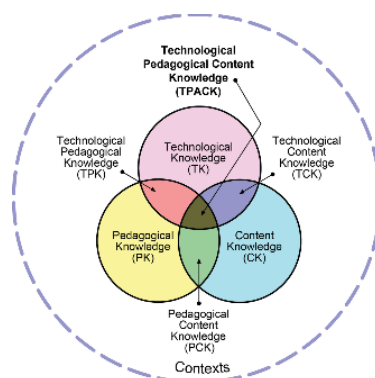


Figure 1 TPACK Framework

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 teacher candidates (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. 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 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.

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)

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

- Ho₁: TPK has no significant effect on TPACK.
- Ha₁: TPK simultaneously has a significant effect on TPACK.
- Ho₂: TCK has no significant effect on TPACK.
- Ha₂: TCK simultaneously has a significant effect on TPACK.

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 $Y = 1.752 + 0.452X_1 + 0.524X_2$.

From the analyses, the researchers concluded the correlation of the variables based on the R-square values. Table 5 shows the results.

Table 5 R Square

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

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.

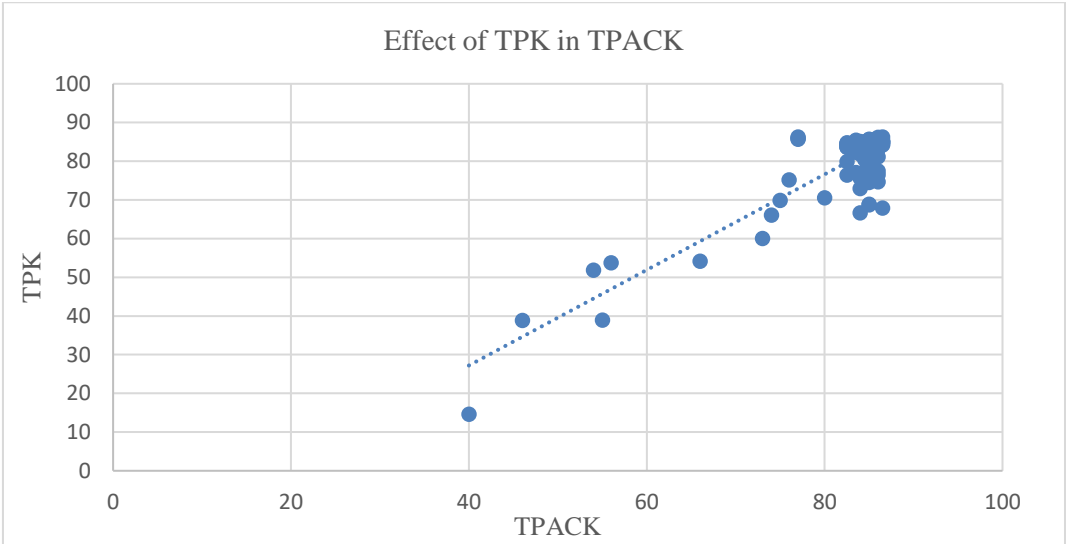


Figure 2 Effect Of TPK in TPACK

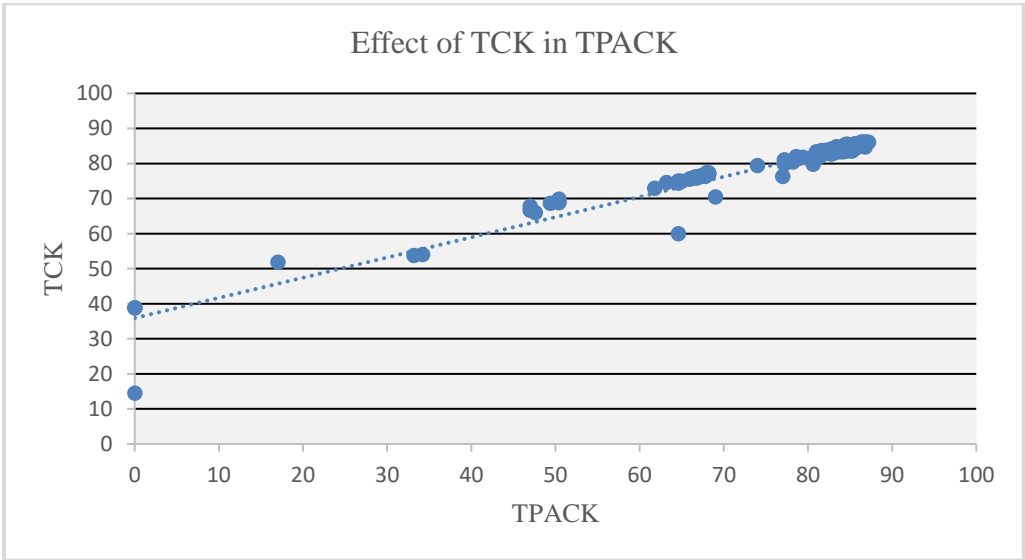


Figure 3 Effect of TPK in TPACK

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 TPACK 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 delivered 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 1 shows a linear correlation between TPK competence and TPACK while figure 2 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 deals 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, teacher candidates 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, an individual 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 teacher candidates (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 teacher candidates. In this research, the applied curriculum prepared the teacher candidates in teacher professional education. The teacher candidates 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 prepare 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 to 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

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Conflict of Interest

There is no conflict of interest in this research.

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References

- Abdullateef, S., T. (2021). Remote Learning: Fostering Learning of 21st Century Skills through Digital Learning Tools. *Arab World English Journal*, 7(1), 190–201. <https://doi.org/10.24093/awej/call7.14>
- Albeta, S. W., Firdaus, L. N., Copriady, J., & Alimin, M. (2023). TPACK-based blended learning as an implementation of progressivism education: A systematic literature review. *Jurnal Pendidikan Vokasi*, 13(1), 44–59. <https://doi.org/10.21831/jpv.v13i1.51287>
- Alcivar, Carmen Magdalena Mero, Tatiana Lizeth Ibarra Quimi, M. F. Z. B. c. (2020). The motivation and its importance in the teaching-learning process. *International Research Journal of Management, IT and Social Sciences*, 7(1), 138–144. <https://doi.org/10.21744/irjmis.v7n1.832>
- Almonacid-Fierro, A. (2023). *International Journal of Educational Methodology Analysis of Pedagogical Content Knowledge in Science Teacher Education: A Systematic Review 2011-2021*. 9(3), 525–534.
- Antinluoma, M., Ilomaki, L., Lahti-Nuuttila, P., & Toom, A. (2018). Schools as Professional Learning Communities. *Journal of Education and Learning*, 7(5), 76. <https://doi.org/10.5539/jel.v7n5p76>
- Anud, Edgar and Caro, V. (2022). Teaching Performance of Science Teachers in the New Normal and Their Technological Pedagogical and Content Knowledge (Tpack) Self-Efficacy. *International Journal of Applied Science and Research*, 05(04), 81–84. <https://doi.org/10.56293/ijasr.2022.5410>
- Arnold, J., & Mundy, B. (2020). Praxis pedagogy in teacher education. *Smart Learning Environments*, 7(1). <https://doi.org/10.1186/s40561-020-0116-z>
- Aydede, M. N. (2022). Examining the Primary School Teacher Candidates' Science Learning Skills in Terms of Their Attitudes towards Science and Their Science Teaching Self-Efficacy Beliefs. *International Journal of Educational Methodology*, 8(4), 853–864. <https://doi.org/10.12973/ijem.8.4.853>
- Cabrera, L., Diane Jass Ketelhut, Kelly Mills, Heather Killen, Merijke Coenraad, Virginia L. Byrne, J. D. P. (2023). Designing a Framework for Teachers' Integration of Computational Thinking into Elementary Science. *Journal of Research in Science Teaching in Science Education*, June. <https://doi.org/10.1002/tea.21888>
- Cakir, M. (2008). Constructivist approaches to learning in science and their implication for science pedagogy: A literature review. *International Journal of Environmental and Science Education*, 3(4), 193–206.
- Creswell, J. W., & Creswell, J. D. (2018). Mixed Methods Procedures. In *Research Defign: Qualitative, Quantitative, and Mixed*

Methods Approaches.

- Doğan, S., & Julian, D. (2021). Collaborative Community Problem Solving: A Model and Recommendations to Support Community Practice. *Ahi Evran Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 7(1), 1–14. <https://doi.org/10.31592/aeusbed.676547>
- Fakhriyah, F., Masfuah, S., Hilyana, F. S., & Mamat, N. (2022). Analysis of Technological Pedagogical Content Knowledge (Tpack) Ability Based on Science Literacy for Pre-Service Primary School Teachers in Learning Science Concepts. *Jurnal Pendidikan IPA Indonesia*, 11(3), 399–411. <https://doi.org/10.15294/jpii.v11i3.37305>
- Fakhriyah, F., Masfuah, S., Roysa, M., Rusilowati, A., & Rahayu, E. S. (2017). Student's science literacy in the aspect of content science? *Jurnal Pendidikan IPA Indonesia*, 6(1), 81–87. <https://doi.org/10.15294/jpii.v6i1.7245>
- Fariyani, Q., Mubarak, F. K., Masfu'ah, S., & Syukur, F. (2020). Pedagogical Content Knowledge of Pre-service Physics Teachers. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 9(1), 99–107. <https://doi.org/10.24042/jipfalbiruni.v9i1.3409>
- Fitzgerald, A., & Smith, K. (2016). Science that matters: Exploring science learning and teaching in primary schools. *Australian Journal of Teacher Education*, 41(4), 64–78. <https://doi.org/10.14221/ajte.2016v41n4.4>
- Garraway-Lashley, Y. M. (2019). Teaching Science at the Primary school Level: "Problems Teachers' are facing". *Asian Journal of Education and E-Learning*, 7(3), 81–94. <https://doi.org/10.24203/ajeel.v7i3.5847>
- Gopo, C. (2022). The Role of Technology in the Architecture of the 21st Century. *The Official Research Journal of Tagum City Division*.
- Granjeiro, É. M. (2019). Research-based teaching-learning method: A strategy to motivate and engage students in human physiology classes. *Advances in Physiology Education*, 43(4), 553–556. <https://doi.org/10.1152/advan.00034.2019>
- Hair, J. F., Ringle, C. M., & Sarstedt, M. (2013). Partial Least Squares Structural Equation Modeling: Rigorous Applications, Better Results and Higher Acceptance. *Long Range Planning*, 46(1–2), 1–12. <https://doi.org/10.1016/j.lrp.2013.01.001>
- Helaluddin, Fitriyyah, D., Rante, S. V. N., Tulak, H., Ulfah, M., St., & Wijaya, H. (2023). Gen Z students perception of ideal learning in post-pandemic: A phenomenological study from Indonesia. *International Journal of Educational Methodology*, 9(2), 423–434. <https://doi.org/10.12973/ijem.9.2.423>
- Hilyana, F. S., Fakhriyah, F., & Masfuah, S. (2023, June). Analysis on the ability of primary teacher education lecturers in TPACK-based E-learning. In *AIP Conference Proceedings* (Vol. 2614, No. 1). AIP Publishing.
- Jan, H., (2017). Teacher of 21st Century: Characteristics and Development. *Research on Humanities and Social Sciences*, 7(9), 2225–0484. www.iiste.org
- Joo, Y. J., Park, S., & Lim, E. (2018). Factors Influencing Preservice Teachers' Intention to Use Technology: TPACK, Teacher Self-efficacy, and Technology Acceptance Model. *Journal of Educational Technology & Society*, 21(3), 48–59. <http://www.jstor.org/stable/26458506>
- Koehler, M. J., Mishra, P., Kereluik, K., Shin, T. S., & Graham, C. R. (2014). The technological pedagogical content knowledge framework. *Handbook of research on educational communications and technology*, 101–111.
- Kereluik, K., Mishra, P., Fahnoe, C., & Terry, L. (2013). What Knowledge Is of Most Worth. *Journal of Digital Learning in Teacher Education*, 29(4), 127–140. <https://doi.org/10.1080/21532974.2013.10784716>
- Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content (TPACK)? *Journal of Education*, 193(3): 13–19. <https://www.researchgate.net/publication/260281100>
- Koehler, M.J. and Mishra, P. (2008) 'Introducing TPCK. AACTE Committee on Innovation and Technology (Ed.): The Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators, pp.3–29, Lawrence Erlbaum Associates, Mahwah, NJ.
- Koh J. H. L, Ching Sing Chai, & Ching-Chung Tsai. (2014). Demographic Factors, TPACK Constructs, and Teachers' Perceptions of Constructivist-Oriented TPACK. *Journal of Educational Technology & Society*, 17(1), 185–196. <http://www.jstor.org/stable/jeductechsoci.17.1.185>
- Koh, J. H. L., Chai, C. S., & Lim, W. Y. (2017). Teacher Professional Development for TPACK-21CL: Effects on Teacher ICT Integration and Student Outcomes. *Journal of Educational Computing Research*, 55(2), 172–196. <https://doi.org/10.1177/0735633116656848>
- Koh, J. H. L., Chai, C. S., Benjamin, W., & Hong, H. Y. (2015). Technological Pedagogical Content Knowledge (TPACK) and Design Thinking: A Framework to Support ICT Lesson Design for 21st Century Learning. *Asia-Pacific Education Researcher*, 24(3), 535–543. <https://doi.org/10.1007/s40299-015-0237-2>
- Kuloğlu, A., & Karabekmez, V. (2022). The Relationship Between 21st-century Teacher Skills and Critical Thinking Skills of Classroom Teacher. In *International Journal of Psychology and Educational Studies* (Vol. 9, Issue 1, pp. 91–101).

<https://doi.org/10.52380/ijpes.2022.9.1.551>

Kumari, K., & Yadav, S. (2018). Linear regression analysis study. *Journal of the Practice of Cardiovascular Sciences*, 4(1), 33. https://doi.org/10.4103/jpcs.jpcs_8_18

Masfuah, S., & Fakhriyah, F. (2017). The Aspect of Science Literacy for Students of Elementary School Education Program Through the Application of Project Based Learning. *Unnes Science Education Journal*, 6(3), 1708–1716. <http://journal.unnes.ac.id/sju/index.php/usej%0ADEVELOPING>

Messina, L., & Tabone, S. (2012). Integrating Technology into Instructional Practices Focusing on Teacher Knowledge. *Procedia - Social and Behavioral Sciences*, 46(2011), 1015–1027. <https://doi.org/10.1016/j.sbspro.2012.05.241>

Munna, A. S., & Kalam, M. A. (2021). Teaching and learning process to enhance teaching effectiveness: literature review. *International Journal of Humanities and Innovation (IJHI)*, 4(1), 1–4. <https://doi.org/10.33750/ijhi.v4i1.102>

OECD. (2020). Technical Report 2022. (2022).

Okoye, K., Arrona-Palacios, A., Camacho-Zuñiga, C., Hammout, N., Nakamura, E. L., Escamilla, J., & Hosseini, S. (2020). Impact of students evaluation of teaching: a text analysis of the teachers qualities by gender. *International Journal of Educational Technology in Higher Education*, 17(1). <https://doi.org/10.1186/s41239-020-00224-z>

Önen, Z., & Sincar, M. (2019). An analysis of teacher's performance evaluation at private schools: Kahramanmaraş and gaziantep sample. *Educational Administration: Theory and Practice*, 25(1), 169–190. <https://doi.org/10.14527/kuey.2019.005>

Prahani, B. K., Amiruddin, M. Z., Suprpto, N., Deta, U. A., & Cheng, T. H. (2022). The trend of physics education research during COVID-19 pandemic. *International Journal of Educational Methodology*, 8(3), 517-533. <https://doi.org/10.12973/ijem.8.3.517>

Rohandi, R. (2017). Teaching and Learning Science: Students' Perspective. *International Journal of Indonesian Education and Teaching*, October, 16–31. <https://doi.org/10.24071/ijiet.2017.010103>

Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, 46(8), 909–921. <https://doi.org/10.1002/tea.20327>

Sojanah, J., Suwatno, Kodri, & Machmud, A. (2021). Factors affecting teachers' technological pedagogical and content knowledge (A survey on economics teacher knowledge). *Cakrawala Pendidikan*, 40(1), 1–16. <https://doi.org/10.21831/cp.v40i1.31035>

Suganda, H., Riandi, R., & Purwianingsih, W. (2021). TPACK perception analysis of teachers in facing 21st-century learning. *Jurnal Bioedukatika*, 9(2), 93. <https://doi.org/10.26555/bioedukatika.v9i2.17788>

Susanti, N., Hadiyanto, & Mukminin, A. (2022). The Effects of TPACK Instrument Variables on Teacher Candidates in Higher Education. *Journal of Higher Education Theory and Practice*, 22(2). <https://doi.org/10.33423/jhetp.v22i2.5041>

Tsekhmister, Y. (2022). Effectiveness of Practical Experiences in Using Digital Pedagogies in Higher Education: A Meta-Analysis. *Journal of Higher Education Theory and Practice*, 22(15), 138-150. <https://doi.org/10.33423/jhetp.v22i15.5567>

Ucak, E. (2019). "Science teaching and science teachers" from students' point of view. *International Journal of Educational Methodology*, 5(2), 221-233. <https://doi.org/10.12973/ijem.5.2.221>

Virtue, E., Maddox, G., & Pfaff, K. (2019). The Lasting Effects of Learning Communities. *Learning Communities Research and Practice*, 7(2), 6.

Weinstein, Y., Madan, C. R., & Sumeracki, M. A. (2018). Teaching the science of learning. *Cognitive Research: Principles and Implications*, 3(1). <https://doi.org/10.1186/s41235-017-0087-y>

Wismath, S. L., & Orr, D. (2015). The Canadian Journal for the Scholarship of Teaching and Learning Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning. *The Canadian Journal for the Scholarship of Teaching and Learning*, 6(3). http://ir.lib.uwo.ca/cjsotl_rcacea%5Cnhttp://ir.lib.uwo.ca/cjsotl_rcacea/vol6/iss3/10

Wong, C. L., Chu, H. E., & Yap, K. C. (2020). A Framework for Defining Scientific Concepts in Science Education. *Asia-Pacific Science Education*, 6(2), 615–644. <https://doi.org/10.1163/23641177-bja10010>

Young, J.R. (2016). Unpacking TPACK in Mathematics education research: A systematic review of meta-analyses. *International Journal of Educational Methodology*, 2(1), 19-29. <https://doi.org/10.12973/ijem.2.1.19>

Afdal, H. W., & Spernes, K. (2018). Designing and redesigning research-based teacher education. *Teaching and Teacher Education*, 74, 215-228.

Nagatsu, M., Davis, T., DesRoches, C. T., Koskinen, I., MacLeod, M., Stojanovic, M., & Thorén, H. (2020). Philosophy of science for sustainability science. *Sustainability Science*, 15, 1807-1817.

- 458 Wenglein, S., Bauer, J., Heininger, S., & Prenzel, M. (2015). Kompetenz angehender Lehrkräfte zum Argumentieren mit Evidenz:
459 Erhöht ein Training von Heuristiken die Argumentationsqualität. *Unterrichtswissenschaft*, 43(3), 209-224.

18. Published <https://www.malque.pub/ojs/index.php/msj/article/view/2245>

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ABSTRACT REFERENCES

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 $Y = 1.752 + 0.452X_1 + 0.524X_2$. 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.

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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 $Y = 1.752 + 0.452X_1 + 0.524X_2$. 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 skills 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.



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).

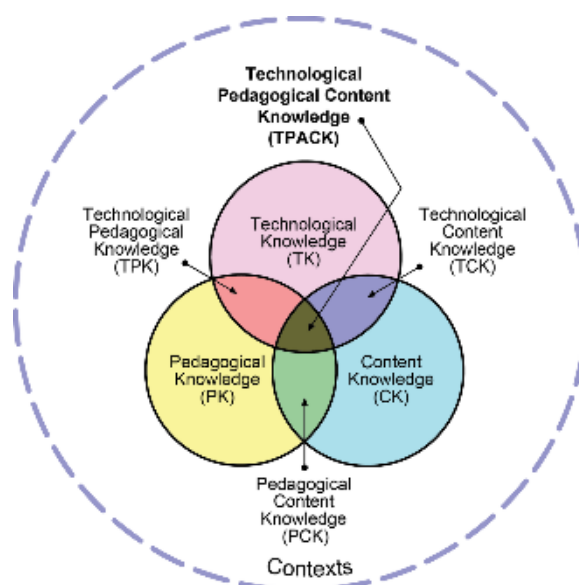


Figure 1 TPACK Framework.

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.

3.2. 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.

- Ho₁: TPK has no significant effect on TPACK.
- Ha₁: TPK simultaneously has a significant effect on TPACK.
- Ho₂: TCK has no significant effect on TPACK.
- Ha₂: 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

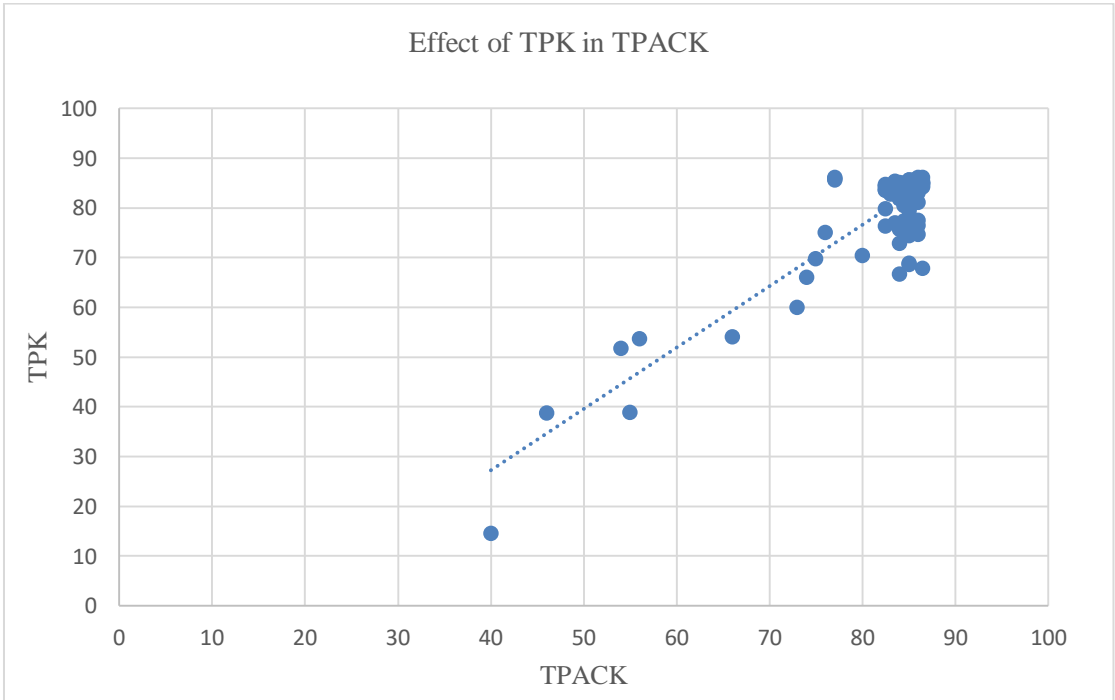


Figure 2 Effect Of TPK in TPACK.

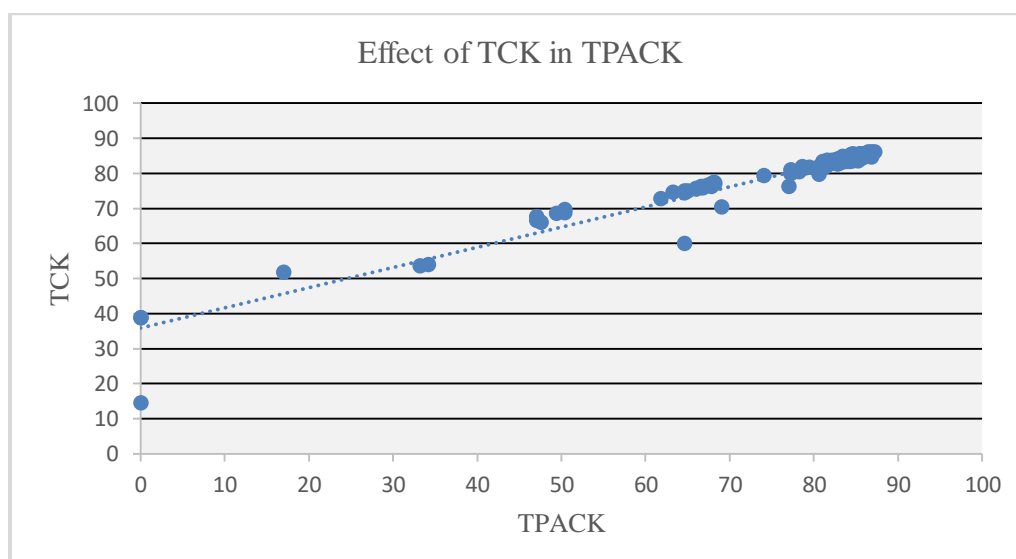


Figure 3 Effect of TPK in TPACK.

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 $Y = 1.752 + 0.452X_1 + 0.524X_2$. 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 delivered 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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References

- Abdullateef, S., T. (2021). Remote Learning: Fostering Learning of 21st Century Skills through Digital Learning Tools. *Arab World English Journal*, 7(1), 190–201. <https://doi.org/10.24093/awej/call7.14>
- Albeta, S. W., Firdaus, L. N., Copriady, J., & Alimin, M. (2023). TPACK-based blended learning as an implementation of progressivism education: A systematic literature review. *Jurnal Pendidikan Vokasi*, 13(1), 44–59. <https://doi.org/10.21831/jpv.v13i1.51287>
- Alcivar, Carmen Magdalena Mero, Tatiana Lizeth Ibarra Quimi, M. F. Z. B. c. (2020). The motivation and its importance in the teaching-learning process. *International Research Journal of Management, IT and Social Sciences*, 7(1), 138–144. <https://doi.org/10.21744/irjmis.v7n1.832>
- Almonacid-Fierro, A. (2023). International Journal of Educational Methodology Analysis of Pedagogical Content Knowledge in Science Teacher Education: A Systematic Review 2011-2021. 9(3), 525–534.
- Antinluoma, M., Ilomaki, L., Lahti-Nuuttila, P., & Toom, A. (2018). Schools as Professional Learning Communities. *Journal of Education and Learning*, 7(5), 76. <https://doi.org/10.5539/jel.v7n5p76>
- Anud, Edgar and Caro, V. (2022). Teaching Performance of Science Teachers in the New Normal and Their Technological Pedagogical and Content Knowledge (Tpack) Self-Efficacy. *International Journal of Applied Science and Research*, 5(4), 81–84. <https://doi.org/10.56293/ijasr.2022.5410>
- Arnold, J., & Mundy, B. (2020). Praxis pedagogy in teacher education. *Smart Learning Environments*, 7(1). <https://doi.org/10.1186/s40561-020-0116-z>
- Aydede, M. N. (2022). Examining the Primary School Teacher Candidates' Science Learning Skills in Terms of Their Attitudes towards Science and Their Science Teaching Self-Efficacy Beliefs. *International Journal of Educational Methodology*, 8(4), 853–864. <https://doi.org/10.12973/ijem.8.4.853>
- Cabrera, L., Ketelhut, D. J., Mills, K., Killen, H., Coenraad, M., Byrne, V. L., Plane, J. D. (2023). Designing a Framework for Teachers' Integration of Computational Thinking into Elementary Science. *Journal of Research in Science Teaching in Science Education*, June, 1-36. <https://doi.org/10.1002/tea.21888>
- Cakir, M. (2008). Constructivist approaches to learning in science and their implication for science pedagogy: A literature review. *International Journal of Environmental and Science Education*, 3(4), 193–206.
- Creswell, J. W., & Creswell, J. D. (2018). Mixed Methods Procedures. In *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*.
- Doğan, S., & Julian, D. (2021). Collaborative Community Problem Solving: A Model and Recommendations to Support Community Practice. *Ahi Evran Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 7(1), 1–14. <https://doi.org/10.31592/aeusbed.676547>
- Fakhriyah, F., Masfuah, S., Hilyana, F. S., & Mamat, N. (2022). Analysis of Technological Pedagogical Content Knowledge (Tpack) Ability Based on Science Literacy for Pre-Service Primary School Teachers in Learning Science Concepts. *Jurnal Pendidikan IPA Indonesia*, 11(3), 399–411. <https://doi.org/10.15294/jpii.v11i3.37305>
- Fakhriyah, F., Masfuah, S., Roysa, M., Rusilowati, A., & Rahayu, E. S. (2017). Student's science literacy in the aspect of content science? *Jurnal Pendidikan IPA Indonesia*, 6(1), 81–87. <https://doi.org/10.15294/jpii.v6i1.7245>
- Fariyani, Q., Mubarak, F. K., Masfua'h, S., & Syukur, F. (2020). Pedagogical Content Knowledge of Pre-service Physics Teachers. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 9(1), 99–107. <https://doi.org/10.24042/jipfalbiruni.v9i1.3409>
- Fitzgerald, A., & Smith, K. (2016). Science that matters: Exploring science learning and teaching in primary schools. *Australian Journal of Teacher Education*, 41(4), 64–78. <https://doi.org/10.14221/ajte.2016v41n4.4>
- Garraway-Lashley, Y. M. (2019). Teaching Science at the Primary school Level: "Problems Teachers' are facing". *Asian Journal of Education and E-Learning*, 7(3), 81–94. <https://doi.org/10.24203/ajeel.v7i3.5847>
- Gopo, C. (2022). The Role of Technology in the Architecture of the 21st Century. The Official Research Journal of Tagum City Division.
- Granjeiro, É. M. (2019). Research-based teaching-learning method: A strategy to motivate and engage students in human physiology classes. *Advances in Physiology Education*, 43(4), 553–556. <https://doi.org/10.1152/advan.00034.2019>
- Hair, J. F., Ringle, C. M., & Sarstedt, M. (2013). Partial Least Squares Structural Equation Modeling: Rigorous Applications, Better Results and Higher Acceptance. *Long Range Planning*, 46(1–2), 1–12. <https://doi.org/10.1016/j.lrp.2013.01.001>
- Helaluddin, Fitriyyah, D., Rante, S. V. N., Tulak, H., Ulfah, M., St., & Wijaya, H. (2023). Gen Z students perception of ideal learning in post-pandemic: A phenomenological study from Indonesia. *International Journal of Educational Methodology*, 9(2), 423-434. <https://doi.org/10.12973/ijem.9.2.423>
- Hilyana, F. S., Fakhriyah, F., & Masfuah, S. (2023, June). Analysis on the ability of primary teacher education lecturers in TPACK-based E-learning. In *AIP Conference Proceedings* (Vol. 2614, No. 1). AIP Publishing.
- Jan, H., (2017). Teacher of 21st Century: Characteristics and Development. *Research on Humanities and Social Sciences*, 7(9), 2225–0484. www.iiste.org
- Joo, Y. J., Park, S., & Lim, E. (2018). Factors Influencing Preservice Teachers' Intention to Use Technology: TPACK, Teacher Self-efficacy, and Technology Acceptance Model. *Journal of Educational Technology & Society*, 21(3), 48–59. <http://www.jstor.org/stable/26458506>
- Koehler, M. J., Mishra, P., Kereluik, K., Shin, T. S., & Graham, C. R. (2014). The technological pedagogical content knowledge framework. *Handbook of research on educational communications and technology*, 101-111.
- Kereluik, K., Mishra, P., Fahnoe, C., & Terry, L. (2013). What Knowledge Is of Most Worth. *Journal of Digital Learning in Teacher Education*, 29(4), 127–140. <https://doi.org/10.1080/21532974.2013.10784716>
- Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content (TPACK)? *Journal of Education*, 193(3), 13-19. <https://www.researchgate.net/publication/260281100>
- Koehler, M.J. and Mishra, P. (2008) 'Introducing TPCK. AACTE Committee on Innovation and Technology (Ed.): The Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators, pp.3–29, Lawrence Erlbaum Associates, Mahwah, NJ.
- Koh J. H. L, Ching Sing Chai, & Ching-Chung Tsai. (2014). Demographic Factors, TPACK Constructs, and Teachers' Perceptions of Constructivist-Oriented TPACK. *Journal of Educational Technology & Society*, 17(1), 185–196. <http://www.jstor.org/stable/jeductechsoci.17.1.185>
- Koh, J. H. L., Chai, C. S., & Lim, W. Y. (2017). Teacher Professional Development for TPACK-21CL: Effects on Teacher ICT Integration and Student Outcomes. *Journal of Educational Computing Research*, 55(2), 172–196. <https://doi.org/10.1177/0735633116656848>
- Koh, J. H. L., Chai, C. S., Benjamin, W., & Hong, H. Y. (2015). Technological Pedagogical Content Knowledge (TPACK) and Design Thinking: A Framework to Support ICT Lesson Design for 21st Century Learning. *Asia-Pacific Education Researcher*, 24(3), 535–543. <https://doi.org/10.1007/s40299-015-0237-2>

- Kuloğlu, A., & Karabekmez, V. (2022). The Relationship Between 21st-century Teacher Skills and Critical Thinking Skills of Classroom Teacher. *In International Journal of Psychology and Educational Studies*, 9(1), 91–101. <https://doi.org/10.52380/ijpes.2022.9.1.551>
- Kumari, K., & Yadav, S. (2018). Linear regression analysis study. *Journal of the Practice of Cardiovascular Sciences*, 4(1), 33. https://doi.org/10.4103/jpcs.jpcs_8_18
- Masfuah, S., & Fakhriyah, F. (2017). The Aspect of Science Literacy for Students of Elementary School Education Program Through the Application of Project Based Learning. *Unnes Science Education Journal*, 6(3), 1708–1716. <http://journal.unnes.ac.id/sju/index.php/usej%0ADEVELOPING>
- Messina, L., & Tabone, S. (2012). Integrating Technology into Instructional Practices Focusing on Teacher Knowledge. *Procedia - Social and Behavioral Sciences*, 46(2011), 1015–1027. <https://doi.org/10.1016/j.sbspro.2012.05.241>
- Munna, A. S., & Kalam, M. A. (2021). Teaching and learning process to enhance teaching effectiveness: literature review. *International Journal of Humanities and Innovation (IJHI)*, 4(1), 1–4. <https://doi.org/10.33750/ijhi.v4i1.102>
- OECD. (2020). Technical Report 2022. (2022).
- Okoye, K., Arrona-Palacios, A., Camacho-Zuñiga, C., Hammout, N., Nakamura, E. L., Escamilla, J., & Hosseini, S. (2020). Impact of students evaluation of teaching: a text analysis of the teachers qualities by gender. *International Journal of Educational Technology in Higher Education*, 17(1). <https://doi.org/10.1186/s41239-020-00224-z>
- Önen, Z., & Sincar, M. (2019). An analysis of teacher's performance evaluation at private schools: Kahramanmaraş and gaziantep sample. *Educational Administration: Theory and Practice*, 25(1), 169–190. <https://doi.org/10.14527/kuey.2019.005>
- Prahani, B. K., Amiruddin, M. Z., Suprpto, N., Deta, U. A., & Cheng, T. H. (2022). The trend of physics education research during COVID-19 pandemic. *International Journal of Educational Methodology*, 8(3), 517–533. <https://doi.org/10.12973/ijem.8.3.517>
- Rohandi, R. (2017). Teaching and Learning Science: Students' Perspective. *International Journal of Indonesian Education and Teaching*, October, 16–31. <https://doi.org/10.24071/ijiet.2017.010103>
- Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, 46(8), 909–921. <https://doi.org/10.1002/tea.20327>
- Sojanah, J., Suwatno, Kodri, & Machmud, A. (2021). Factors affecting teachers' technological pedagogical and content knowledge (A survey on economics teacher knowledge). *Cakrawala Pendidikan*, 40(1), 1–16. <https://doi.org/10.21831/cp.v40i1.31035>
- Suganda, H., Riandi, R., & Purwianingsih, W. (2021). TPACK perception analysis of teachers in facing 21st-century learning. *Jurnal Bioedukatika*, 9(2), 93. <https://doi.org/10.26555/bioedukatika.v9i2.17788>
- Susanti, N., Hadiyanto, & Mukminin, A. (2022). The Effects of TPACK Instrument Variables on Teacher Candidates in Higher Education. *Journal of Higher Education Theory and Practice*, 22(2). <https://doi.org/10.33423/jhetp.v22i2.5041>
- Tsekhmister, Y. (2022). Effectiveness of Practical Experiences in Using Digital Pedagogies in Higher Education: A Meta-Analysis. *Journal of Higher Education Theory and Practice*, 22(15), 138–150. <https://doi.org/10.33423/jhetp.v22i15.5567>
- Ucak, E. (2019). "Science teaching and science teachers" from students' point of view. *International Journal of Educational Methodology*, 5(2), 221–233. <https://doi.org/10.12973/ijem.5.2.221>
- Virtue, E., Maddox, G., & Pfaff, K. (2019). The Lasting Effects of Learning Communities. *Learning Communities Research and Practice*, 7(2), 6.
- Weinstein, Y., Madan, C. R., & Sumeracki, M. A. (2018). Teaching the science of learning. *Cognitive Research: Principles and Implications*, 3(1). <https://doi.org/10.1186/s41235-017-0087-y>
- Wismath, S. L., & Orr, D. (2015). The Canadian Journal for the Scholarship of Teaching and Learning Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning. *The Canadian Journal for the Scholarship of Teaching and Learning*, 6(3). http://ir.lib.uwo.ca/cjsotl_rcacea%5Cnhttp://ir.lib.uwo.ca/cjsotl_rcacea/vol6/iss3/10
- Wong, C. L., Chu, H. E., & Yap, K. C. (2020). A Framework for Defining Scientific Concepts in Science Education. *Asia-Pacific Science Education*, 6(2), 615–644. <https://doi.org/10.1163/23641177-bja10010>
- Young, J.R. (2016). Unpacking TPACK in Mathematics education research: A systematic review of meta-analyses. *International Journal of Educational Methodology*, 2(1), 19–29. <https://doi.org/10.12973/ijem.2.1.19>
- Afdal, H. W., & Spernes, K. (2018). Designing and redesigning research-based teacher education. *Teaching and Teacher Education*, 74, 215–228.
- Nagatsu, M., Davis, T., DesRoches, C. T., Koskinen, I., MacLeod, M., Stojanovic, M., & Thorén, H. (2020). Philosophy of science for sustainability science. *Sustainability Science*, 15, 1807–1817.
- Wenglein, S., Bauer, J., Heininger, S., & Prenzel, M. (2015). Kompetenz angehender Lehrkräfte zum Argumentieren mit Evidenz: Erhöht ein Training von Heuristiken die Argumentationsqualität. *Unterrichtswissenschaft*, 43(3), 209–224.