



Analysis of Pre-Service Science Teachers' Technological Pedagogical Content Knowledge (TPACK) Ability in Online Learning

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Abstract: The development of Information, Communication, and Technology (ICT) impacts Education 5.0 to improve the quality and equity of education services in Indonesia, especially in science learning. This study aims to analyze the ability of pre-service science teachers to use TPACK (Technology Pedagogical Content Knowledge) in online learning. The survey research method is used to get information about TPACK pre-service science teachers' ability to carry out online learning. The sample consisted of 132 pre-service science teachers from education Universities in Indonesia. The research instrument consisted of 42-item questionnaires that assessed TPACK components in online learning. The results showed that the percentage of pre-service science teachers' average score on TPACK ability is 79.87%. The percentage of average scores for each component TPACK is 78.68% for Pedagogical Knowledge (PK), 79.54% for Content Knowledge (CK), 80.73% for Technological Knowledge (TK), 78.94 for Pedagogical Content Knowledge (PCK), 81.73% for Technology Pedagogical Knowledge (TPK), 80.98% for Technology Content Knowledge (TCK), and 78.64% for TPACK. The highest average scores on TPACK are TPK, TCK, and TK. It is concluded that pre-service science teachers' TPACK skills in online learning related to the use of technology are superior to content knowledge and pedagogy.

Keywords: online learning; pre-service science teachers; TPACK

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INTRODUCTION

Information, Communication, and Technology (ICT) use in school learning is increasing (Akram & Khan, 2020; Supriyanto & Amrin, 2022). Furthermore, the Indonesian curriculum also supports the use of ICT in learning in schools because ICT plays a vital role in the implementation of learning (Ullah et al., 2020; Adarkwah, 2021), and it is in line with the industrial revolution 4.0 (Syamsuar & Reflianto, 2019; Rahim et al., 2019). Therefore, the utilization of ICT is needed to learn effectively and efficiently. The preparation of pre-service teachers for the use of ICT in schools is considered a priority of teacher training institutions in many countries (König et al., 2020; Tondeur et al., 2020).

Teachers play a key role in using technology in education (Starkey, 2020). Teachers must have technological literacy in integrating technology into education (Romijn et al., 2021; Ridhuan et al., 2022). The use of technology in education facilitates teaching activities both for teachers and students. Li and Keller (2018) show that motivations directly related to technology-based teaching to students and their academic achievement and motivation increase. Vongkulluksn et al. (2018) state that teachers who use technology spend more time teaching in the classroom. In addition, the importance of the relationship between technology literacy and education is emphasized by Malik et al. (2019) with the Technology Pedagogical Content Knowledge (TPACK) model.

In TPACK, several components are related to and support teacher knowledge: technological knowledge (TK), content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), technology content knowledge (TCK), and Technology Pedagogical Content Knowledge (TPACK). According to the TPACK framework, the use of technological equipment is not just teachers having access to the tool and learning the skills how to use it. However, teachers must think carefully about the potential of technology in solving pedagogical problems when designing learning. This means that teachers decide how to select, adapt, and apply appropriate materials, pedagogy, and technologies that can meaningfully add value to learning with technology in the classroom, leading to student-centered learning.

Previous studies have addressed TPACK analysis for pre-service teachers or teachers worldwide (Schmid et al., 2020; Castéra et al., 2020). Schmid et al. (2020) state that technology pedagogical content knowledge (TPACK) is considered one of the most important models that describe teachers' competence in successfully teaching with technology. Furthermore, Castéra et al. (2020) state the importance of improving TPACK's ability

for teachers to integrate technology into teacher training programs or teacher education. The study of [Castéra et al. \(2020\)](#) focused on TPACK teacher educators as one of the most important elements in school teacher training. It has been proven that most educators believe that the integration of technology into the classroom is an easy task that requires only technological skills. [Tondeur et al. \(2020\)](#) show a positive and significant link between the perception of TPACK pre-service teachers and their perception of the strategies applied in Education Workforce Education Institutions that training pre-service teachers plays an important role in improving TPACK. However, previous research has not discussed the analysis of TPACK ability of pre-service teachers, especially in science subjects, in carrying out online learning. Meanwhile, pre-service science teachers are one factor that holds the key to successful learning in the 21st century. This is the novelty of this study compared to previous studies.

Teachers should have skills, like 21st-century skills, to achieve effective technological integration in line with evolving technologies ([Daeli & Fitriasari, 2025](#)). In addition, teachers and pre-service teachers must integrate technology in their classrooms in line with new technologies, and they must go through dynamic and complex processes that include technology, pedagogy, and content knowledge. This is particularly important because of this complex process, as it is used in the teaching and learning process and has been part of the demands of the 2013 curriculum, which requires teachers to integrate technology into the learning process ([Verawati & Nisrina, 2025](#)). This definition also includes difficulties in the integration process. During the implementation of online learning, the Minister of Education and Culture of the Republic of Indonesia stated that a teacher must have information or data literacy skills, use technology involving communication and interaction, produce digital content that is appropriate to the course, solve possible problems related to technology and have sufficient knowledge about the content of the knowledge of the taught subjects ([Fibonacci et al., 2024](#)).

TPACK was developed as a conceptual framework by incorporating technological knowledge within the "pedagogical content knowledge" framework, as suggested by [Shulman \(1986\)](#). By expanding the framework ([Malik et al., 2019](#)), technological knowledge is added as a separate area of effect, demonstrating that, primarily, digital technology has changed (or will most likely change) the quality of classrooms. The TPACK framework defines the knowledge a teacher needs to teach with technology. This framework covers seven areas: Content Knowledge (CK), Pedagogical Knowledge (PK), Technology Knowledge (TK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), Technological Pedagogical Content Knowledge (TPACK).

TPACK measurements are carried out to determine the level of knowledge of pre-service teachers, lecturers, tutors, and those engaged in education as educators. This activity is carried out to assess the level of technological pedagogical and content knowledge (TPACK) using the TPACK Framework. On measurements, the level of mastery of a person's TPACK is seen as the ability to integrate technology into learning and learning ([Schmid et al., 2021](#)). At least three benefits are obtained when taking TPACK measurements. First, through TPACK measurements, a TPACK mastery profile was found that can describe the level of mastery rank in each domain of knowledge. Second, TPACK measurement can be reflected in implementing education for pre-service teachers. Third, the impact of learning interventions related to the integration of technology provided to pre-service teachers when pursuing teacher education is determined. Thus, analyzing pre-service science teachers' TPACK abilities in online learning is important. This research aims to analyze pre-service science teachers' TPACK abilities in online learning. Hopefully, this research will benefit pre-service science teachers in opening up insights that TPACK abilities is essential to master. This research also contributes to one of the considerations in government policies to improve teachers' TPACK abilities.

METHODS

This research uses a cross-sectional design with a survey method ([Mageda et al., 2023](#)). The research was conducted by going directly into the field to examine how well pre-service science teachers' Technological Pedagogical and Content Knowledge (TPACK) ability in implementing online science learning. The TPACK questionnaire used in the study included 42-item statements of 5 Likert scale criteria that can be seen in Table 1. The pedagogical content knowledge (PCK) and technological pedagogical knowledge (TPK) were measured using two perspectives by the developers of the TPACK questionnaire. In the first stage, general statements do not depend on specific pedagogical applications or theories about learning. This statement follows previous TPACK evaluation tools, such as pedagogical and technological knowledge. The second phase includes pedagogical statements based on 21st-century skills (e.g., cooperative, creative thinking, and problem-solving). On the TPACK scale, a 21st-century skills approach is selected and adapted to online learning. The questionnaire focuses on TPACK from 7 perspectives: Content Knowledge (CK), Pedagogical Knowledge (PK), Technology Knowledge (TK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), Technological Pedagogical Content Knowledge (TPACK).

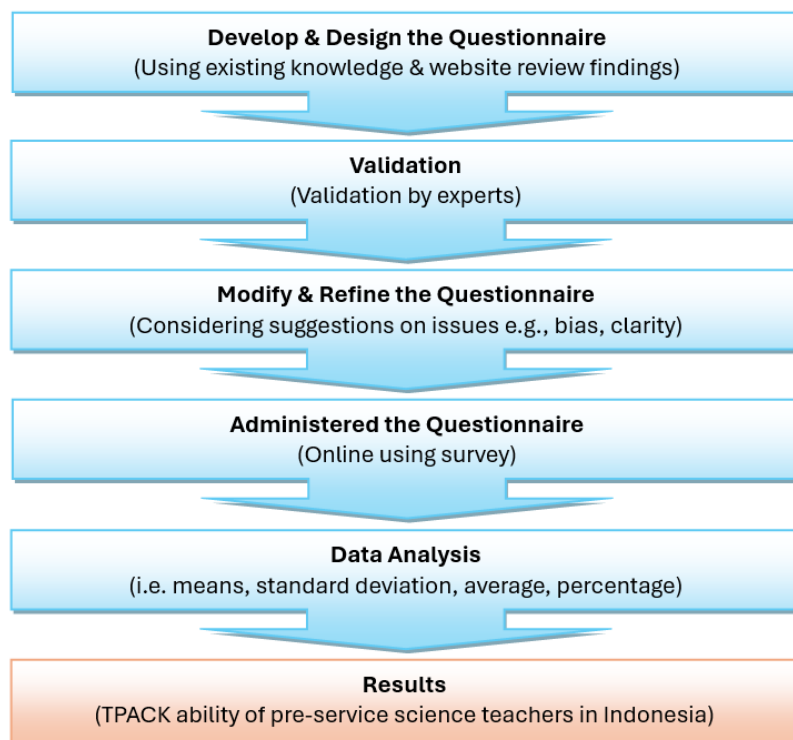


Figure 1. Flow Chart for the Questionnaire Survey Process

This study analyzes the ability of pre-service science teachers to implement online learning using the TPACK framework. The results of the study are divided into two parts: the first part will discuss the development of the TPACK questionnaire instrument, and the second part will discuss the self-assessment of the TPACK questionnaire by pre-service science teachers. The TPACK instrument for pre-service science teachers who carry out online learning was developed as a conceptual framework by incorporating technological knowledge into the "pedagogical content knowledge framework." The TPACK framework in this study defines the knowledge needed for science teacher candidates to teach with technology in online learning. This framework covers seven areas: Pedagogical Knowledge (PK) with 7 statement items, Content Knowledge (CK) with 6 statement items, Technology Knowledge (TK) with 7 statement items, Pedagogical Content Knowledge (PCK) with 6 statement items, Technological Pedagogical Knowledge (TPK) with 5 statement items, Technological Content Knowledge (TCK) with 6 statement items, Technological Pedagogical Content Knowledge (TPACK) with 5 statement items. The TPACK instrument was adapted from Schmid et al. (2020), and the authors developed several statement items. The TPACK questionnaire instrument for science teacher candidates in carrying out online learning can be seen in Table 1.

Table 1. Aspects of TPACK for pre-service science teachers in carrying out online learning

Variable	Item code	Item
Pedagogical Knowledge (PK)	PK1	I can adapt my teaching based on what students understand or do not understand for online learning.
	PK2	I can adapt my teaching style to different learners in online learning.
	PK3	I can use a variety of teaching approaches in an online classroom setting.
	PK4	I can assess students in online learning in a variety of ways.
	PK5	I know how to assess student performance in online classes.
	PK6	I understand students' conceptual understanding and misconceptions in online science learning.
	PK7	I know how to set up and maintain online classroom management.
Content Knowledge (CK)	CK1	I have sufficient knowledge of science subjects.
	CK2	I can deliver science subject material online.
	CK3	I know the basic theories and concepts of the science subjects I teach.
	CK4	I know the history and development of important theories in science subjects.
	CK5	I have a variety of ways and strategies to develop my understanding of the science subjects I teach.
	CK6	I understand and am familiar with the latest research in science subjects.

Technology Knowledge (TK)	TK1	I keep up with important new technologies that can be used for online learning.
	TK2	I often use this technology in the implementation of online learning.
	TK3	I know about the many different technologies that can be used for online learning.
	TK4	I have the skills I need to use technology for online learning.
	TK5	If there is a problem with using technology in online learning, I know how to solve the technical problem.
	TK6	I can quickly learn the latest technology used in online learning.
	TK7	I have enough opportunities to utilize different technologies for online learning.
Pedagogical Content Knowledge (PCK)	PCK1	I know how to choose an effective learning approach to practice students' understanding and skills in science subjects.
	PCK2	I know how to develop appropriate tasks to improve students' complex thinking in science subjects.
	PCK3	I know how to develop exercises that students can use to improve their knowledge in science learning.
	PCK4	I know how to evaluate students' performance in science subjects.
	PCK5	I can explain important content in science subjects in a way that students can understand.
	PCK6	In science lessons, I can identify students' misconceptions where there are difficulties in understanding the material and give appropriate feedback.
Technological Pedagogical Knowledge (TPK)	TPK1	I can choose online learning technologies that enhance my teaching approach to science subjects.
	TPK2	I can choose online learning technologies that improve students' understanding of science lessons.
	TPK3	I can adapt the use of online learning technology that I learn for various science teaching activities.
	TPK4	I know how to use online learning technology effectively in the classroom.
	TPK5	The curriculum has made me think more deeply about how online learning technologies are used in science learning.
Technological Content Knowledge (TCK)	TCK1	I know how to develop learning media in science subjects online.
	TCK2	I can explain the technology used in the research of science subjects in online learning conditions.
	TCK3	I know new technologies that are currently being used in the implementation of online science learning.
	TCK4	I know how to use online technology to participate in science research.
	TCK5	I know technology and online learning media that help me understand science subjects.
	TCK6	I know how to use technology and important learning media, specifically for science subjects online.
Technological Pedagogical Content Knowledge (TPACK)	TPACK1	I can use learning strategies that combine content, online learning technology, and online learning approaches in science subjects.
	TPACK2	I can choose online learning technology that can improve the content of science subjects.
	TPACK3	I can choose the online learning technology used in science subjects that can improve the quality of teaching methods and science materials that students learn.
	TPACK4	I can teach science subjects by combining content, online learning technology, and teaching approaches.
	TPACK5	I can be a leader who helps other science teachers combine science subject content, online learning technology, and teaching approaches at the school level.

The list of students who filled out the TPACK questionnaire self-assessment came from 18 universities in Indonesia, with 132 students. To measure TPACK and technology integration in natural science online learning, the TPACK questionnaire was given through Google Forms and then reported in descriptive analysis. The TPACK questionnaire was surveyed through 42 items. Participants rated their perception with each item on the 5-point Likert scale (5 = Strongly Agree, 4 = Agree, 3 = Neither agree nor disagree, 2 = Disagree, 1 =

Strongly Disagree). The size of the TPACK domain used in the study represented participants' self-assessment of their knowledge of online science learning. The target of the TPACK questionnaire self-assessment is science education students.

RESULT AND DISCUSSION

This research analyzes how pre-service science teachers in Indonesia can implement online learning using the TPACK framework. The results of the study are spelled out into two parts: the first part will discuss the development of TPACK questionnaire instruments, and the second part will discuss the assessment of TPACK questionnaire by pre-service science teachers. Before the TPACK questionnaire instrument of pre-service science teachers in carrying out online learning is disseminated, experts who consisted of three science lecturers are validated. The results of the validation can be seen in Table 2.

Table 2. Validation analysis of the TPACK questionnaire of pre-service science teachers

Indicators	Average	Percentage	Criteria
A. Presentation Aspects			
1. Presentation of the complete statement following the TPACK framework (CK, PK, TK, PCK, TCK, TPK, TPACK).	4.3		
2. Each statement in the TPACK instrument does not contain ambiguous and confusing sentences.	4.0	82%	Very good
3. Each statement item follows the indicators in each TPACK framework of pre-service science teachers in carrying out online learning	4.0		
B. Construction Aspects			
4. The statement on the TPACK instrument is formulated and does not give rise to a double meaning.	3.7	80%	Good
5. Statements on TPACK instruments are formulated in communicative and easy-to-understand language.	4.3		
C. Content Quality Aspects			
6. The statement in the instrument can identify the ability of TPACK of pre-service science teachers to carry out online learning.	4.3	86%	Very good
7. Instruments can analyze the level of TPACK ability of pre-service science teachers in carrying out online learning.	4.3		

The average percentage of validation results of TPACK questionnaires for aspects of presentation was 82% with very good criteria, construction aspects 80% with good criteria, and aspects of content quality by 86% with very good criteria. Based on the validation results, the average percentage was 82.67%, and the criteria were very good. After pre-service science teachers fill out the TPACK questionnaire, the data is analyzed using SPSS to look for mean grades and Standard Deviation (SD) in the TPACK component of pre-service science teachers in carrying out online learning—the results of the SPSS processing analysis of each TPACK component. Table 3 presents data analysis of mean value and Standard Deviation (SD) in the TPACK component of pre-service science teachers in carrying out online learning.

Table 3. Distributional Statistics for Domains of TPACK Component

		PK	CK	TK	PCK	TPK	TCK	TPACK
N	Valid	132	132	132	132	132	132	132
	Missing	0	0	0	0	0	0	0
	Mean	27.54	23.86	28.26	23.68	20.43	24.30	19.66
	Std. Error of Mean	.321	.262	.325	.269	.225	.252	.244
	Median	28.00	24.00	28.00	24.00	20.00	24.00	20.00
	Std. Deviation	3.683	3.008	3.737	3.095	2.581	2.897	2.809
	Variance	13.563	9.050	13.964	9.577	6.659	8.393	7.891
	Range	25	23	26	24	20	20	18
	Minimum	9	7	9	6	5	10	7
	Maximum	34	30	35	30	25	30	25
	Sum	3635	3150	3730	3126	2697	3207	2595
Percentiles	25	25.00	22.00	26.00	22.00	20.00	23.00	19.00
	50	28.00	24.00	28.00	24.00	20.00	24.00	20.00
	75	30.00	26.00	31.00	24.75	21.00	25.75	20.75

Table 3 shows the distributional statistics for domains of the TPACK component of pre-service science teachers in online learning. The TPACK average percentage and standard deviation are shown in Table 4.

Table 4. The TPACK average percentage and Standard Deviation

TPACK aspect	TPACK average percentage (%)	Standard Deviation
PK	78.68	3.68
CK	79.54	3.00
TK	80.73	3.74
PCK	78.94	3.09
TPK	81.73	2.58
TCK	80.98	2.90
TPACK	78.64	2.81
Overall TPACK	79.87	3.11

Table 4 shows the TPACK average percentage and standard deviation in the TPACK component of pre-service science teachers in online learning. The results showed that the percentage of pre-service science teachers' average score on TPACK ability is 79.87%. The current study aims to analyze pre-service science teachers' TPACK abilities in online learning. The percentage of the average scores for each component TPACK is 78.68% for Pedagogical Knowledge (PK), 79.54% for Content Knowledge (CK), 80.73% for Technological Knowledge (TK), 78.94 for Pedagogical Content Knowledge (PCK), 81.73% for Technology Pedagogical Knowledge (TPK), 80.98% for Technology Content Knowledge (TCK), and 78.64% for TPACK (Technology Pedagogical Content Knowledge). Based on this percentage of average scores, the highest average score is on TPK, followed by TCK and TK. This means that pre-service science teachers' TPACK abilities in online learning regarding the use of T "technology" is superior to the knowledge of content and pedagogy.

The results revealed that there is a relationship between TPACK and technology. Schmid et al. (2021) show positive relations between TPACK components and technology use in lesson plans. Raygan and Moradkhani (2022) provide an opportunity for independent assessment of different types of teacher knowledge defined by the TPACK framework. TPACK can assist pre-service teacher preparation programs by integrating technology into learning. Purwaningsih et al. (2020) stated that technology integration in learning is not only putting a computer in a class without training or purpose. Instead, technology leads to development only if it is associated with effectiveness, efficiency, and meaning. Pre-service science teachers should update their technological knowledge and be informed about how technology can improve teaching quality, including implementing TPACK in learning. Therefore, pre-service science teachers must have TPACK skills in teaching science.

TPACK ability of pre-service science teachers in online learning consists of seven components: Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Knowledge (TK), Pedagogical Content Knowledge (PCK), Technology Pedagogical Knowledge (TPK), Technology Content Knowledge (TCK), and TPACK (Technology Pedagogical Content Knowledge). Implementing TPACK in learning means that the pre-service science teachers implement 7 components of TPACK in learning. Pedagogical Knowledge (PK) is related to learning models and methods used. The use of learning models and learning methods is adapted to the needs of the class and students. The example of learning models that can be integrated with TPACK is Project Based-Learning (PjBL) (Dewi et al., 2022; Shafie et al., 2019; Tejada & Morel, 2019; Ekawati & Prastyo, 2022), Problem-based Learning (PBL) (Stefani et al., 2021; Tseng et al., 2022; Tanjung et al., 2022; Chaidam & Poonputta, 2022), Discovery learning (Mannong et al., 2021; Sholihah & Rusyana, 2023; Elhani et al., 2023), and inquiry learning (Waluyo, 2021).

Content Knowledge (CK) is related to the material used in science learning. TPACK can be implemented on various science materials. Agustin et al. (2019) assessed pre-service science teachers' TPACK on kinematics, plant tissue, and daily life material. Fakhriyah et al. (2022) implemented a TPACK training model for tackling the ongoing challenges of COVID-19 on evolution, microscopic measurement technology, and earthquake material. Utami and Muhtadi (2020) implemented TPACK in chemistry materials. The researchers stated that developing teaching materials integrated with TPACK is necessary. CK is significant for teachers in the learning process. CK here is knowledge of the thinking framework's concepts, theories, facts, ideas, and principles.

Technological Knowledge (TK) is related to the technology used in science learning. Technology in science learning includes searching for literature sources or learning references online via students' mobile phones or computers (Widiyatmoko et al., 2024). Students will get a lot of new knowledge and insights just by using gadgets used daily. Learning can be more meaningful using technology in the revolution 4.0 era. However, technology here can also be interpreted using books, teaching aids, and other media (Widiyatmoko et al., 2023). Aulia et al. (2021) developed a STEM-TPACK e-module for increasing students' science literacy and concluded

that scientific literacy skills students' after being treated are better than scientific literacy students' before being treated. Students and teachers have indirectly applied technology to learning by accessing this electronic module. Pedagogical Content Knowledge (PCK) is related to the material implemented in specific learning models. PCK involves choosing the correct method or strategy for the characteristics of the material (Utami & Muhtadi, 2020). Purwaningsih et al. (2020) used PBL models through TPACK in momentum and impulse material. Hence, science learning with that material using the PBL syntax resulted in students' problem-solving skills increasing after they attended learning by using the developed device. Students were also more excited, happy, and comfortable in learning physics. PCK is the teacher's capability of determining the topic of material content, teaching a particular material content with multiple representations, and illustrating material so that students easily understand the material (Purwaningsih et al., 2020).

Technology Pedagogical Knowledge (TPK) is related to the learning methods implemented in science learning integrated with technology. Teachers are expected to be familiar with current learning technologies to gain broad knowledge about technology (Utami & Muhtadi, 2020). Technology Content Knowledge (TCK) is related to the material implemented with technology. Meanwhile, TPACK relates to implementing technology, pedagogy, and content knowledge in science learning. Through the TPACK components, the utilization of technology in learning is under its functions and needs (Utami & Muhtadi, 2020). In addition, improving TPACK will help the lecturers to use technology as a tool, which will be a part of the whole process of teaching and not just a tool to assist the teaching process (Chukwuemeka & Iscioglu, 2016).

CONCLUSION

The results showed that the percentage of pre-service science teachers' average score on TPACK ability is 79.87%. The percentage of average scores for each component TPACK is 78.68% for Pedagogical Knowledge (PK), 79.54% for Content Knowledge (CK), 80.73% for Technological Knowledge (TK), 78.94 for Pedagogical Content Knowledge (PCK), 81.73% for Technology Pedagogical Knowledge (TPK), 80.98% for Technology Content Knowledge (TCK), and 78.64% for TPACK (Technology Pedagogical Content Knowledge). Based on this percentage of average scores, the highest average scores are on TPK, followed by TCK and TK. This means that pre-service science teachers' TPACK abilities in online learning regarding the use of technology are superior to the knowledge of content and pedagogy. The widening awareness of meaningful integration of technology in science learning can potentially widen the pre-service science teachers in future projects. Hopefully, this research will benefit pre-service science teachers in opening up insights that TPACK abilities are crucial to master. This research also contributes to one of the considerations in government policies to improve teachers' TPACK abilities.

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