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Investigation of TPACK Skills of Elementary to Secondary School Teachers in the Context of Educational Technology: Profile and Challenges

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Abstract: This research addresses a gap in previous studies that typically focus on a single education level, lacking comparative analysis across primary to secondary education. The study explores the TPACK (Technological Pedagogical Content Knowledge) profiles and barriers faced by mathematics teachers at different educational levels. Previous research often lacks an in-depth examination of these barriers in mathematics teaching. The novelty lies in its multi-level comparative approach, offering insights rarely discussed in existing literature. Using mixed methods, including in-depth interviews, classroom observations, and document analysis, the study provides comprehensive data through triangulation. Findings indicate variations in TPACK skills among mathematics teachers in Banjarmasin. An elementary school teacher exhibited excellent TPACK skills despite insufficient learning documents. A junior high school teacher showed adequate skills but faced similar document preparation issues. A high school teacher displayed excellent skills with complete supporting documents. Differences in TPACK skill profiles stem from barriers such as limited technological access and infrastructure, inadequate training, high workload, teachers' attitudes toward technology, and unsupportive institutional policies. This research underscores the need for tailored interventions to address these barriers and enhance TPACK skills across educational levels.

Keywords: Elementary to secondary school teachers; Profile and challenges; TPACK

Introduction

Information and communication technology (ICT) has become an integral part of various aspects of life, including in the field of education (Scherer et al., 2018; Tondeur et al., 2017). The use of technology in the learning process is expected to improve the quality of education and students' abilities. One approach that is relevant in this context is Technological Pedagogical and Content Knowledge (TPACK), which is a framework for understanding and designing technology integration in education (Willermark, 2018; Durdu & Dag, 2017). TPACK is a conceptual framework that combines three main components: content (content knowledge), pedagogy (pedagogical knowledge), and technology (technological knowledge) (Baran et al., 2011; Mishra & Yadav, 2016). This framework was introduced by Mishra et al. (2006) and has since become an important reference in research on technology integration in education. In the context of mathematics education, TPACK provides guidance for teachers to combine their knowledge of mathematics, pedagogical strategies, and effective use of technology in the learning process (Niess & Gillow, 2016).

This research focuses on investigating the profile and barriers faced by mathematics teachers in

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implementing TPACK in the classroom. Teachers' TPACK profiles include their understanding and ability to integrate technology with mathematics pedagogy and content as well as barriers to integrating technology. Previous studies show that although many teachers are aware of the importance of technology integration, the implementation of TPACK still faces various obstacles. For example, research by Scherer et al. (2018) found that teachers often lack confidence in using technology effectively in teaching. Additionally, Dong et al. (2020) identified that institutional support and adequate training are critical to increasing TPACK implementation in schools. Additional references such as research by Chai et al. (2013) highlight that the successful implementation of TPACK also depends on teachers' positive attitudes towards technology and their readiness to continue learning and adapting. These factors are important for understanding how mathematics teachers can overcome barriers and develop strong TPACK profiles.

The background to this research is due to the gap in most previous research which tends to focus on one level of education only. There is a lack of comparative studies that examine the differences and similarities in TPACK profiles and the barriers faced by teachers at various levels of education, from primary to secondary schools. Although barriers to implementing TPACK have been discussed in several studies, many of these studies do not provide an in-depth analysis of the barriers faced in mathematics learning (Zhang & Tang, 2021). This gap makes it important for this research to investigate in more detail the profiles and barriers specific to mathematics teaching.

The novelty of this research is a multi-level comparative approach to education, which provides deeper insight into the profiles and barriers to TPACK skills at various levels of education, which are rarely discussed in depth in previous literature. More specifically. The study aims to identify the TPACK profile of mathematics teachers in primary to secondary schools, focusing on their ability to integrate technology, pedagogy, and content knowledge effectively. It seeks to understand how well teachers can use technology to enhance their teaching methods and improve student learning outcomes in mathematics. Additionally, the study analyzes the obstacles faced by these teachers in implementing TPACK, such as limited access to technology, insufficient training, lack of technical support, and resistance to change. By identifying these challenges, the study aims to provide insights and recommendations to improve the integration of TPACK in mathematics education. By understanding the profile and existing barriers, it is hoped that this research can make a significant contribution to the development of more effective and innovative mathematics learning strategies through technology integration.

Method

This research uses mixed methods (Plano-Clark et al, 2015). Where to quantitatively examine the TPACK profile of elementary, middle and high school teachers using the TPACK instrument by means of observation. The TPACK instrument is filled in by the teacher and by the researcher as observer. The observation instrument used to analyze or assess TPACK skills uses a rigorous modification of the instrument or TPACK framework as offered by Mishra et al. (2006) and is designed to measure seven domains of technological, pedagogical and content knowledge.

Technological Knowledge (TK) includes eight indicators: mastering technological tools, understanding software and hardware, quickly adapting to new technologies, understanding digital security and ethics, using the internet and applications, solving basic technical problems, using social media for learning, and utilizing digital collaboration tools. Pedagogical Knowledge (PK) includes four indicators: understanding learning principles, mastering teaching techniques, managing the classroom, and understanding assessment strategies. Content Knowledge (CK) includes six indicators: understanding subject matter, key concepts, relating theory to practice, staying updated in the field, understanding curriculum standards, and identifying quality learning resources. Technological Pedagogical Knowledge (TPK) includes three indicators: integrating technology in teaching, understanding technology's impact on learning, and enhancing interaction with technology. Technological Content Knowledge (TCK) includes three indicators: using technology to present content, mastering specialized tools, and evaluating technological resources. Pedagogical Content Knowledge (PCK) includes three indicators: linking teaching methods to content, conveying subject matter clearly, and developing content-appropriate strategies. Technological Pedagogical Content Knowledge (TPACK) includes three indicators: combining technology, pedagogy, and content for holistic learning, using technology to enhance content understanding, and selecting appropriate technological tools for learning. The following is the research procedure, see figure 1.

A total of three schools were selected using a random sampling technique in the city of Banjarmasin, namely 1 teacher from each school who teaches mathematics at the elementary, middle and high school levels. Data obtained in the field through observation was processed using quantitative analysis and the results of interviews with teachers used qualitative analysis. Next, the observation data was analyzed using the Miles and Huberman method, namely data reduction (Miles et al., 2020). The techniques and tools used to collect research data are learning observation sheets and interview sheets as well as document analysis in the form of lesson plans, teacher assessments and student grades. Data analysis procedures the observation instrument uses a Likert scale ranging from 1-4. Where 1 state very poor, 2 states poor, 3 states good, and 4 states very good, according to Table 1 (Turner, 2017). The equation (1) used to convert the score obtained into a percentage is as follows.

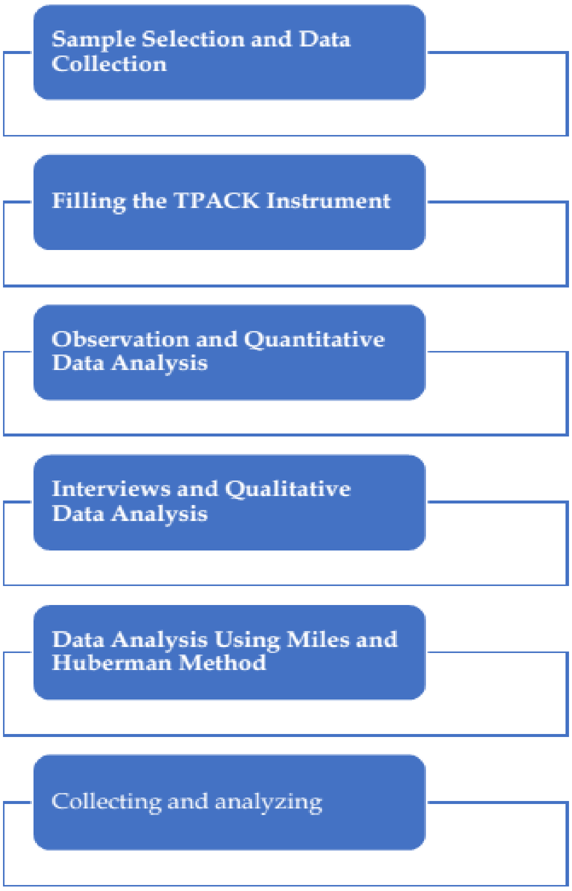

Figure 1. Research procedure

Table 1. Likert Scale Categories

Intervals	Criteria
1.00 < score ≤ 1.75	Very Poor (SK)
1.75 < score ≤ 2.50	Less (K)
2.50 < score ≤ 3.25	Good (B)
3.25 < score ≤ 4.00	Very Good (SB)

$$\text{Score} = \frac{\text{obtained score}}{\text{maximum score}} \times 100\% \quad (1)$$

The data obtained was then transformed into qualitative criteria in table 2. In order for the research data to have validity and reduce bias, the researcher conducted data triagulation (Denzin, 2017) from three sources, namely classroom observations by looking at the learning process in the classroom carried out by the teacher, conducting in-depth interviews with the teacher, and analyzing learning documents.

Table 2. Qualitative Criteria

Intervals	Criteria
0 – 20	Very Poor (SK)
21 – 40	Less (K)
41 – 60	Enough (C)
61 – 80	Good (B)
81 – 100	Very Good (SB)

Qualitatively, this research uses in-depth interview sheets regarding mathematics teachers' TPACK skills in the classroom learning process. To triagulate research data, researchers also use document analysis, namely lesson plans, assessment sheets, LKPD, PPT, learning reflection sheets, and other supporting learning documents. The following is the triangulation of data used in this research (see Figure 2).

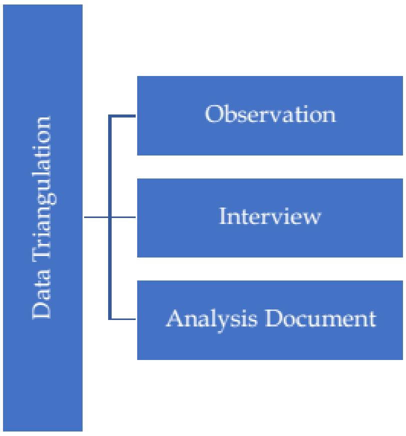

Figure 2. Data triangulation

Result and Discussion

The results of this research consist of observations using the TPACK instrument, descriptions of interview results, and document analysis. The results of observations obtained by researchers on the learning activities of elementary, middle and high school teachers in the classroom can be seen in filling in the observation instruments related to assessment indicators for all components in TPACK. The results of filling in the elementary teacher observation instrument can be seen in Table 3.

Table 3. Results of Filling in the Observation Instrument with Elementary School Teachers

No	Statement	Answer			
		SK 1	K 2	B 3	SB 4
Technological Knowledge (TK)					
1	Master the technology used well				√
2	The technology used has an appeal to students				√
3	The technology used succeeded in increasing student interest and motivation				√
4	The technology used is easy to operate				√
5	The technology used is appropriate with current development				√
6	The technology used is appropriate to the student's level of understanding				√
7	The technology used helps solve problems			√	
8	Usinglearning media in accordancewith student characteristics				√
Pedagogical Knowledge (PK)					
9	Use varied learning strategies and according to students' level of understanding			√	
10	Master and manage the class well			√	
11	Take reflective action to improve the quality of learning			√	
12	Using varied assessment techniques in learning evaluation			√	
Content Knowledge (CK)					
13	Integrate various mathematical concepts in material that requires a combination of these concepts in solving mathematical problems that will be taught to students			√	
14	Provide relevant examples inimprove student understanding			√	
15	Deliver material logically, clearly, and in accordance with the RPP			√	
16	Answer students' questions appropriately related to the mathematics material being taught			√	
17	Using the latest sources (articles, books, internet, etc.) to increase knowledge of the material being taught			√	
18	Master the material taught			√	
Technological Pedagogical Knowledge (TPK)					
19	Use technology that is appropriate to the learning approaches, strategies, models and methods used				√
20	Using technology/computer/internet-based learning media in implementing learning, such as in collecting assignments or teaching materials used or implementing other learning.			√	
21	Utilize technology to learningmathematics according to the characteristics of students			√	
Technological Content Knowledge (TCK)					
22	The technology used is appropriate/relevant to the mathematics material being taught			√	
23	Providing opportunities for students to utilize technology to strengthen mathematical concepts (such as developing student activities and assignments that involve the use of technology)				√
24	The technology used can improve student understanding			√	
Pedagogical Content Knowledge (PCK)					
25	Use learning approaches or strategies that are appropriate to the mathematics material being taught			√	
26	The teacher carries out cognitive, psychomotor and affective assessments according to the content in the mathematics material being taught			√	
27	Provide exerciseto measure students' understanding of the material taught			√	
Technological Pedagogical Content Knowledge (TPACK)					
28	Combining mathematics knowledge, pedagogical knowledge and technological knowledge of teachers to create effective learning			√	
29	Choose learning strategies and technology that are appropriate to the mathematical material used in learning activities.				√
30	Applying appropriate learning strategies and technology that is appropriate to the mathematics material used in learning				√

Table 4. Results of Filling in the Observation Instrument with Junior High School Teachers

No	Statement	Answer			
		SK 1	K 2	B 3	SB 4
Technological Knowledge (TK)					
1	Master the technology used well				√
2	Technologyused has an appeal to students				√
3	The technology used succeeded in increasing student interest and motivation				√
4	The technology used is easy to operate				√
5	The technology used is in accordance with current developments				√
6	Using learning media that align with students' characteristics				√
7	The technology used helps solve problems			√	
8	Using learning media that suits student characteristics				√
Pedagogical Knowledge (PK)					
9	Use varied learning strategies and according to students' level of understanding			√	
10	Master and manage the class well			√	
11	Take reflective action to improve the quality of learning			√	
12	Using varied assessment techniques in learning evaluation			√	
Content Knowledge (CK)					
13	Integrating various mathematical concepts in material that requires a combination of these concepts in solving mathematical problems that will be taught to students		√		
14	Provide relevant examples to increase student understanding			√	
15	Deliver material logically, clearly, and in accordance with the RPP			√	
16	Answer students' questions appropriately related to the mathematics material being taught			√	
17	Using the latest sources (articles, books, internet, etc.) to increase knowledge of the material being taught			√	
18	Master the material taught			√	
Technological Pedagogical Knowledge (TPK)					
19	Use technology that is appropriate to the learning approaches, strategies, models and methods used		√		
20	Usingtechnology/computer/internet-based learning media in implementing learning, such as in collecting assignments or teaching materials used or implementing other learning.		√		
21	Utilize technology to learningmathematics according to the characteristics of students		√		
Technological Content Knowledge (TCK)					
22	The technology used is appropriate/relevant to the mathematics material being taught			√	
23	Providing opportunities for students to utilize technology to strengthen mathematical concepts (such as developing student activities and assignments that involve the use of technology)		√		
24	The technology used can enhance students' understanding.			√	
Pedagogical Content Knowledge (PCK)					
25	Use learning approaches or strategies that are appropriate to the mathematics material being taught			√	
26	The teacher carries out cognitive, psychomotor and affective assessments according to the content in the mathematics material being taught			√	
27	Provide exercises to measure students' understanding of the material being taught				√
Technological Pedagogical Content Knowledge (TPACK)					
28	Combining mathematics knowledge, pedagogical knowledge and technological knowledge of teachers to create effective learning		√		
29	Selecting appropriate learning strategies and technology with acceptthematics used in Learning Activities.		√		
30	Applying appropriate learning strategies and technology that is appropriate to the mathematics material used in learning		√		

Table 5. Results of Filling in the Observation Instrument with High School Teachers

No	Statement	Answer			
		SK 1	K 2	B 3	SB 4
Technological Knowledge (TK)					
1	Master the technology used well				√
2	Technology usedhas appeal to students			√	
3	The technology used succeeded in increasing student interest and motivation			√	
4	The technology used is easy to operate.				√
5	The technology used is in accordance with the times.				√
6	The technology used is appropriate to the student's level of understanding			√	
7	The technology used is in line with current developments.			√	
8	Using learning media that suits student characteristics			√	
Pedagogical Knowledge (PK)					
8	Use varied learning strategies and according to students' level of understanding			√	
9	Master and manage the class well				√
10	Take reflective action to improve the quality of learning				√
11	Using varied assessmenttechniques in learning evaluation			√	
Content Knowledge (CK)					
10	Integrating various mathematical concepts in material that requires a combination of these concepts in solving mathematical problems that will be taught to students			√	
11	Engaging in reflective practice to improve the quality of learning				√
12	Deliver material logically, clearly, and in accordance with the RPP			√	
13	Answer students' questions appropriately related to the mathematics material being taught				√
14	Using the latest sources (articles, books, internet, etc.) to increase knowledge of the material being taught				√
15	Master the material taught				√
Technological Pedagogical Knowledge (TPK)					
15	Using technology that aligns with the approaches, strategies, models, and methods of instruction employed.				√
16	Using technology/computer/internet-based learning media in implementing learning, such as in collecting assignments or teaching materials used or implementing other learning.			√	
17	Utilizing technology for mathematics learning according to student characteristics			√	
Technological Content Knowledge (TCK)					
18	The technology used is appropriate/relevant to the mathematics material being taught				√
19	Providing opportunities for students to utilize technology to strengthen mathematical concepts (such as developing student activities and assignments that involve the use of technology)				√
20	The technology used can improve student understanding		√		
Pedagogical Content Knowledge (PCK)					
20	Integrating the teacher's knowledge of mathematics, pedagogy, and technology to achieve effective learning.				√
21	The teacher carries out cognitive, psychomotor and affective assessments according to the content in the mathematics material being taught			√	
22	Provide exercises to measure students' understanding of the material being taught				√
Technological Pedagogical Content Knowledge (TPACK)					
22	Integrating knowledge Mathematics,pedagogical knowledge and technological knowledge that teachers have in realizing effective learning			√	
23	Choose learning strategies and technology that are appropriate to the mathematical material used in learning activities.				√
24	Applying appropriate learning strategies and technology that is appropriate to the mathematics material used in learning				√

The results of filling in the junior high school teacher observation instrument can be seen in Table 4. The results of filling in the high school teacher observation instrument can be seen in Table 5. The analysis of each component based on the results of filling in the observation instrument with elementary, middle and high school teachers is explained in the table below. Table 6 is an analysis for the TK component (Technological Knowledge).

Next is an analysis of the results of interviews with elementary, middle and high school teachers regarding their TPACK challenges and skill profiles. From interviews with elementary school teachers, information was obtained. First, Technology used by teachers: Elementary school teachers useprojectors, cellphones, laptops, and learning videos (YouTube). Middle School Teachers use Mobile Phones for Quizizz. High School Teachers use PPT, Projectors, Mobile Phones, Computers, Learning Videos, Virtual Classrooms, and Live Worksheets; Second, Elementary school teachers stated thatStudents adapt more quickly and feel comfortable in participating in learning. Middle school teachers stated that students felt they were competing in answering questions. High school teachers said they welcomed them and attracted their interest. Their enthusiasm is high, especially when answering questions, if the answer is correct a smiling emote will appear and if it is wrong a crying emote will appear; Third, Elementary teachers stated that students were more enthusiastic and enthusiastic about learning. Middle school teachers expressed only slightly more enthusiasm. High school teachers said students competed to get to the front of the class to choose the answer they thought was correct to see what emote would appear.

Table 6. Analysis of TK Components

Teacher	Scale Mean	Percentage (%)	Qualitative Criteria
Elementary school	3.875	96.875	Very good
Junior high school	2.875	71.875	Good
Senior high school	3.375	84.375	Very good

Table 7. PK Component Analysis

Teacher	Scale Mean	Percentage (%)	Qualitative Criteria
Elementary school	3	75	Good
Junior high school	2.25	56.25	Enough
Senior high school	3.5	87.5	Very good

Table 8. CK Component Analysis

Teacher	Scale Mean	Percentage (%)	Qualitative Criteria
Elementary school	3	75	Good
Junior high school	2.83	70.83	Good
Senior high school	3.67	91.67	Very good

Table 9. Analysis of TPK Components

Teacher	Scale mean	Percentage (%)	Qualitative criteria
Elementary school	3.33	83.33	Very good
Junior high school	2	50	Enough
Senior high school	3.33	83.33	Very good

Table 10. Analysis of TCK Components

Teacher	Scale Mean	Percentage (%)	Qualitative Criteria
Elementary school	3.33	83.33	Very good
Junior high school	2.33	77.78	Good
Senior high school	3.67	91.67	Very good

Table 11. PCK Component Analysis

Teacher	Scale Mean	Percentage (%)	Qualitative Criteria
Elementary school	3	75	Good
Junior high school	2.33	77.78	Good
Senior high school	3.67	91.67	Very good

Table 12. TPACK Component Analysis

Teacher	Scale Mean	Percentage (%)	Qualitative Criteria
Elementary school	3.67	91.67	Very good
Junior high school	2	50	Enough
Senior high school	3.67	91.67	Very good

Table 13. Categories of Mathematics Teachers' TPACK Skills

Teacher	Percentage (%)	Category
Elementary school	82.875	Very good
Junior high school	59.339	Enough
Senior high school	88.875	Very good

Fourth, Elementary school teachers said that the obstacle in the preparation part was finding appropriate games and the lesson material they wanted to teach, which took quite a long time. The middle school teacher said that because the technology used is only cellphones by students, using cellphones is easy. However, schools do not allow children to carry cellphones unless there are certain things that are absolutely necessary. This is because it can make students think more about their cellphones than studying. High school teachers said that at school facilities in the form of computers, LCDs, wifi and projectors were available in the classroom. The obstacle experienced is that creating learning media takes quite a long time; Fifth, suitability of application of learning methods, strategies and models: Elementary school teachers usegame-based learning (Game-Based Learning) according to the characteristics of students who like games. Middle school teachers adapt to the existing facilities at school and the conditions of students. High school teachers use a question and answer strategy by asking students to come to the front of the class. The approach used is a scientific approach, and the model used is discovery learning. According to him, this use is in accordance with the characteristics of class 12 students; Sixth, How to manage a class: Elementary teacher Have a mature learning plan, build good relationships with students, manage time well, rreflection and adapting teaching practice (Ifdaniyah, 2024; Muthi'ah, 2023). Middle school teachers ask questions suddenly to students who are not paying attention noise while the teacher is talking/explaining the material. Teachers also go around when giving assignments to monitor students who are experiencing difficulties. High school teachers divide learning activities specifically between preliminary activities, core activities and closing activities. Where each activity has its own role;

Seventh, how to answer questions, deliver material, and give examples to students: Elementary school teacher answers when delivering material using various learning methods and tools to reach students with different learning styles. Apart from that, students are also given examples that are relevant to real life so that they are easier for students to understand (Ifinedo et al., 2020; Kusnadi, 2023; Saubern et al., 2020; Wati Sukmawati et al., 2023). Middle school teachers answer based on existing material and provide simple examples that students can understand better. High school teachers answer students' questions by giving other students the opportunity to answer first, then the teacher adds other things that have not been covered by the students' answers. Deliver material by relating it to everyday life and bringing visual aids and real examples from everyday life; Eighth, preparing lesson plans or using lesson plans: Elementary and middle school teachers say sometimes use lesson plans in learning. High school teachers use and compile lesson plans at the beginning of the new school year before the students enter school, print them and bind them and then submit them to the curriculum; Ninth, Strategy model or method used in designing lesson plans: elementary school teachers use game-based learning. Middle school teachers use expository learning strategies, cooperative learning models, lecture and question and answer methods. High school teachers use a variety of them, depending on the students' learning materials;

Tenth, mastery of the material: elementary, middle school and high school teachers a like master the material to be taught. However, the high school teacher was more detailed in explaining, where he said mastery was initial capital, sometimes before entering class, at night he reads and repeats the material that will be taught tomorrow; Eleventh, MTech learning materials to students: Elementary school teachers by making lesson plans, providing examples that are relevant to everyday life, providing practice questions, providing constructive feedback. Middle school teachers explain with examples and then ask students to try to solve it themselves. High school teachers stated that students in the class were heterogeneous, there were students who understood easily and there were students who needed extra attention in presenting material in class (Foulger et al., 2022; Ifdaniyah & Sukmawati, 2024; Santos & Castro, 2021; Wahjusaputri et al., 2024). So we as teachers must be able to share our attention with the students, for example, after giving an explanation to the students, we go around the class to find out how the students process in solving the questions given; Twelfth linking mastery of teaching materials, teaching methods, and technology in learning: Elementary teachers utilize existing technology such as learning videos, interactive applications, or educational websites. One thing that is used is to display a word wall so that students have new vocabulary. Middle school teachers very rarely use technology to test students' understanding of the material being taught. High school teachers say that we must first know what material we will teach, after that we can determine in the classroom what kind of learning process we will make, whether it is using PPT, Virtual Class, Live worksheets, Google forms, etc. After going through this series, we can then relate the material, teaching method and what technology we want to use;

Thirteenth, Learning resources used: Elementary school teachers use textbooks and the internet. Middle school teachers said that school books were very limited so that learning resources came from the material provided by the teacher. High school teachers said MGMP, the internet, and fellow subject teachers at school were sources of learning; Fourteenth, form of training used: Elementary school teachers by giving practice questions or by small group discussions. Middle school teachers with written exercises individually and in groups. The high school teacher stated that the form of training given was not too far from the example that had been explained, such as changing the numbers for the first question, and for the next question it was changed, where the previous question became the known part, in the next question it became the part that was asked; Fifteenth, Assessment: Elementary School Teacher Muse formative assessment tests. Middle school teachers with a cognitive assessment of the results of working on written questions and an attitude assessment of their responsibility in submitting assignments on time and their activeness during class learning. The high school teacher said that he used pAttitude assessment, which includes self-assessment and assignment assessment. Meanwhile, the knowledge assessment consists of an oral test assessment and a written test assessment; Sixteenth, Is there an increase in student grades after combining content knowledge, technology and teacher teaching abilities: Elementary school teachers student grades have progressed. There is no significant increase in junior high school teachers. High school teachers said that there was an increase in students' grades.

Document analysis shows that only high school teachers are complete in terms of comprehensive assessment sheets, neatly arranged lesson plans, complete PPTs, available LKPD, and learning reflection sheets. Meanwhile, elementary and middle school teachers do not have many documents to research and only attach lesson plans for 1 meeting which are not structured systematically.

From the results of investigations using data triangulation, it was found that the obstacles that influence mathematics teachers' TPACK skills are: 1) technological access and infrastructure, where limited access to technological devices and adequate infrastructure is one of the main obstacles. Teachers often do not have access to the hardware and software necessary to implement TPACK effectively (Abubakir & Alshaboul, 2023; Celik, 2023; Wahjusaputri et al., 2022). Unstable or unavailable internet networks also hinder the process of integrating technology in teaching. Apart from that, school policies also influence it. This can be proven by observing that teacher A in one of the junior high schools had TPACK skills of only 59.339% in the sufficient category. This is because the school does not have infrastructure for integrating technology in learning, learning resources from the school are still limited, there is a lack of variation or adaptation to student characteristics in terms of strategies, models, approaches and learning methods, as well as policies limiting the use of cellphones in schools (Schmid et al., 2020, 2021; Sukmawati, 2024). On the contrary, this happens in schools that have technology-based learning policies with complete infrastructure and variations in the learning process, such as teacher B in one of the junior high schools and teacher C in one of the high schools in Banjarmasin have very good TPACK skills with percentages of 82.875% and 88.875% respectively. %. The difference in the percentage of these two teachers is also influenced by the completeness of learning documents and the existence of training and professional development such as MGMP. Limited professional support in developing technological and pedagogical knowledge is also an obstacle as seen in the TPACK skills of the middle school teacher. Apart from that, limited time to plan and implement technology-based learning is an obstacle (Fauziah, 2023; Paetsch et al., 2023; Taimalu & Luik, 2019). Teachers are often caught up in administrative workloads and other tasks that take up their time. Lack of time to explore and develop technology-based learning materials also hinders the implementation of TPACK. Teachers' attitudes and perceptions towards the use of technology are also a barrier. Some teachers are more comfortable with traditional teaching methods and feel that the use of technology adds to their workload.

Conclusion

Based on the comprehensive data triangulation involving analysis of observation instruments, interviews, and document analysis, the TPACK skill profiles of teachers in elementary, junior high, and high schools in Banjarmasin reflect varied levels of proficiency and document preparation. Teacher A at an elementary school demonstrates a commendable TPACK skill level at 82.875%, despite gaps in systematic documentation supporting the learning process, such as lesson plans and assessment structures. Similarly, Teacher B at a junior high school exhibits sufficient TPACK skills at 59.339%, with similar deficiencies in comprehensive learning documentation. Conversely, Teacher C at a high school displays exemplary TPACK skills at 88.875%, supported by systematically prepared documents like lesson plans, worksheets, presentations, and assessment sheets. The research identifies common barriers influencing overall TPACK skills across these educational contexts, including limited technological access and infrastructure, inadequate training and professional development opportunities, time constraints, teacher attitudes, and institutional policies. These factors significantly impact the integration of technology in teaching practices. For future research directions, there is a recommendation to delve deeper into effective strategies for overcoming specific obstacles faced by teachers in implementing TPACK. Additionally, comparative studies across regions or countries could illuminate best practices and adaptable models for broader application. The findings underscore the importance of addressing these challenges to enhance TPACK skills among educators. In light of these insights, practical suggestions are proposed to enhance mathematics teachers' TPACK skills. These include governmental and institutional initiatives to increase technological resources, support policy frameworks, and establish sustainable training programs. Moreover, efforts to bolster teachers' technological proficiency and reduce administrative burdens are crucial for fostering effective technology-based learning environments. Encouraging shifts in teachers' attitudes towards technology through targeted programs highlighting its benefits in enhancing mathematics education quality is also recommended. These initiatives aim to empower educators with the skills and resources needed to leverage technology effectively in teaching mathematics.

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