

## The Novice Mathematics Teachers' Technological Pedagogical Content Knowledge: A Case Study

<sup>1</sup>Sadrack Luden Pagiling, <sup>2</sup>Khumaeroh Dwi Nur'aini, & <sup>3</sup>Eka Indrysari Mokoagow

<sup>1,2,3</sup>Universitas Musamus

<sup>1</sup>*pagiling\_fkip@unmus.ac.id*

### Abstract

This study seeks to characterize the Technological Pedagogical Content Knowledge of novice lower secondary mathematics teachers who do and do not possess an educator certificate based on the components of Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK). This research employed a case study approach conducted in two secondary schools in Merauke Regency. Two secondary mathematics teachers with a bachelor's degree in mathematics education and five years of teaching experience were recruited as participants. We collected data from learning classroom observation guidelines, learning-practice interviews, and task-based interviews. Findings show that certified teachers can implement learning according to the lesson plans that have been designed and can teach and answer questions about the assigned material effectively. Meanwhile, the uncertified teacher performs excellently using technology, such as proficiency with WhatsApp, Zoom, Microsoft OneNote, Microsoft PowerPoint, learning videos, and projectors. In contrast, regarding pedagogical and material abilities, the non-certified teachers have yet to be able to apply lesson plans to learning and continue to struggle to answer some predetermined questions.

**Keywords:** novice mathematics teachers, technological pedagogical content knowledge

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### Introduction

Technological Pedagogical Content Knowledge (TPACK) plays a crucial role as a teacher framework in preparing the teaching and learning process (Angeli & Valanides, 2009; Koh & Chai, 2016; Rakes et al., 2022). In addition, this framework provides an overview of the knowledge teachers need concerning teaching subject matter, teaching methods, and learning technologies, including how these three components can be integrated into teaching and learning activities (Graham, 2011; Lyublinskaya & Kaplon-Schilis, 2022). Mishra and Koehler (2006) proposed that TPACK consists of three primary knowledge sources: technology knowledge (TK—teachers' knowledge of technology tools), pedagogical knowledge (PK—teachers' knowledge of instructional pedagogies), and content knowledge (CK—teachers' knowledge of subject matter). These three knowledge sources are depicted as overlapping circles that generate intermediary types of knowledge in their overlap zones. Technological pedagogical knowledge (TPK) is teachers' knowledge of utilizing technology tools to support their pedagogical techniques. Meanwhile, technological content knowledge (TCK) is teachers' knowledge of using technology tools to support content representation. TPACK indicates the overlap between TK, PK, and CK, as well as between TPK, TCK, and PCK. It manifests itself in the form of technology-integrated classes created by teachers.

Niess (2013) proposed the TPACK framework for mathematics teachers at the proficiency level. Within this framework, it has been claimed that teachers progress through the five stages of TPACK: Stage 1 (Recognition), where teachers are able to use the technology and recognize the technology's alignment with the mathematics content, but not the technology in the integrated teaching and learning of mathematics; Stage 2 (Accepting), where teachers develop a positive or negative attitude towards instruction with an appropriate technology; Stage 3 (Adaptation), where teachers make decisions about whether to adopt or reject technologies for teaching and learning; Stage 4 (Explore), where teachers integrate appropriate technology for teaching and learning mathematics; Stage 5 (Advancing), where teachers evaluate the results of incorporating right technology for teaching and learning mathematics. Therefore, mathematics teachers proficient in TPACK can be identified by their ability to integrate technology into their mathematics teaching practice.

Furthermore, Grandgenett, as cited in (Stoilescu, 2015), examined that mathematics teachers with excellent TPACK exhibit six characteristics: 1) openness to experimentation with ICT tools and willingness to experiment with them in new lessons; 2) focus and avoidance of distractions during mathematics teaching concepts through technology; 3) providing sound pedagogical strategies through understanding where students are academic, what students need to know and how the lesson should be taught; 4) supporting students to understand the importance of technology; 5) use of technology for instruction, assessment, and classroom management; and 6) be comfortable and optimistic about technological advances.

In decades, numerous studies have investigated how to assess pre-service and in-service teachers' TPACK (Kim, 2018; Koh, 2019; Mailizar & Fan, 2020; P. G. Smith & Zelkowski, 2022; Zelkowski et al., 2013). The qualitative and quantitative reviews of the TPACK literature (Chai et al., 2016) showed that most previous research evaluating TPACK relied on self-assessment surveys (Abbitt, 2011a; Chai et al., 2013; Handal et al., 2013; Schmidt et al., 2009; Zelkowski et al., 2013), in which different knowledge domains were assessed separately. Although self-assessment tools are easy to use, inexpensive, and can reach many participants, their accuracy in measuring teachers' actual TPACK is limited by respondents' ability to assess their knowledge (Abbitt, 2011b; Kim, 2018). Typically, these surveys assess teachers' views rather than their practical knowledge, which is a construct in its own right (Abbitt, 2011b). To accurately assess TPACK, teachers must show what they can achieve to improve teaching and learning with technology in their subject areas (Voogt et al., 2013).

TPACK's robust assessment is based on observed activities such as virtual classroom and micro-lessons (Oner, 2020), instruction artifacts including lesson plans, student handouts, and lesson portfolios (Akyuz, 2018; Harris et al., 2010; Lyublinskaya & Kaplon-Schilis, 2022; Lyublinskaya & Tournaki, 2011), and knowledge assessments (Lachner et al., 2021) and perhaps be more objective than the self-report.

Several scholars have examined mathematics teachers' TPACK using teaching observation (Njiku, 2023; Patahuddin et al., 2016; Rakes et al., 2022). For instance, Rakes et al. (2022) utilized two validated instruments, namely TPACK levels and the MCOP<sup>2</sup>, in examining teacher candidates' growth in TPACK and effective mathematics teaching practices and the correlation between TPACK and effective mathematics teaching practices. Furthermore, Patahuddin and her colleagues (Patahuddin et al., 2016) employed video

recording of teachers' practice to investigate a series of essential instructional events using TPACK to understand better the knowledge required by teachers to promote students' learning in technology-rich classrooms since videos have the potential to capture the complexity of the learning process. Another study (Njiku, 2023) developed, validated, and presented an observation rubric for assessing mathematics teachers' TPACK and assessed mathematics teachers' TPACK using the developed observation rubric. This study implied that the rubric presented may be used to assess teachers' TPACK but may still need to be more specific depending on the context, such as the teaching subject or topic and the access and kind of technology teachers have. In addition, this study suggested that professional development activities differ in effectiveness and may depend on teachers' level of engagement in the learning process.

Therefore, this study examines teachers' TPACK utilizing task-based interviews, knowledge tests, and teaching observations to obtain more accurate teacher knowledge in incorporating technology. This current study examines teacher TPACK on set concept since it can be a prerequisite to other materials such as function and combinatorics. Moreover, the set material must be possessed by students to gain conceptual understanding in solving contextual problems pertaining to set concepts.

In the context of lower secondary mathematics teachers in Merauke Regency, the previous study uncovered that novice teachers tend to have insufficient pedagogical knowledge since they use monotonous learning strategies, pose problems repeatedly, do not use students' talent to create rich and meaningful learning and do so without being given any descriptions that should be explained differently (Nur'aini & Pagiling, 2020). Novice mathematics teachers who master TPACK will make learning plans and implement more fruitful approaches for students. Kartowagiran (2011) asserted that a novice teacher is new to teaching practices, has less than five years of classroom teaching experience, and can face professional challenges when teaching in schools. One of them is to support the professionalism of teachers to form quality teachers by obtaining teacher certification. Teacher certification is an educational certificate given to teachers who can provide value competence and teacher qualifications in teaching.

Therefore, this study is essential to be conducted since, in Merauke Regency, as part of eastern Indonesia, there is no study on TPACK on mathematics teachers. Moreover, this study can provide a valuable lens on how teachers apply content and pedagogical knowledge in learning and the importance of integrating technology in classroom practice. In doing so, we proposed research questions: How are novice mathematics teachers' Technological Pedagogical Content Knowledge (TPCK) capabilities?

## **Methods**

This current study employed a case study to examine lower secondary mathematics teachers' technological pedagogical content knowledge. We used a case study to accurately identify, describe, and investigate individual secondary mathematics teachers' TPACK components (CK, PCK, TCK, and TPACK). Yin (2018) defined a case study as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not evident; and in which multiple sources

of evidence are used. The participants of this study included two lower secondary mathematics teachers who teach set topics. We administrated these criteria to select research participants: 1) graduated from the Mathematics Education Department, 2) taught in different schools, 3) obtained an educator certificate or not, and 4) the teaching experience of both teachers is between 1-5 years.

The research instrument in this study was the researchers as a critical instrument, assisted with learning practice observation guidelines, learning practice interviews, and task-based interviews on set material. All supporting instruments have been checked for content validity by two mathematics education lecturers.

The observation of classroom practices aims to directly verify the ability of the TPACK teacher to teach set material in the face-to-face class or online class as well as the teacher's strategy in teaching in the form of video recordings to strengthen the data's validity. This observation rubric was developed based on indicators of mathematics knowledge, as depicted in Table 1. Moreover, we interviewed teachers after teaching observation to ask the teacher for confirmation regarding the data the researchers could not find during the learning observation. Meanwhile, we utilized task-based interviews aimed at determining the teacher's proficiency in the set material that has been taught. In this interview, the participants were asked to answer several questions, provide reasons, and work on several questions directly on the paper the researcher had provided. In comparison, the task-based interview aims to dig deeper into the teacher's content knowledge of the set material after observing classroom practices.

To ensure the credibility of the data, the researchers conducted member checks and extended observations. Furthermore, data analysis activities include reducing learning observational data and task-based interviews, data presentation, checking data validity, and drawing conclusions.

In the initial phase, we analyzed teachers' practising on set concepts and interviewed them to examine the consistency. Once the consistency of the data was established, we coded teachers' knowledge and transcripts referring to the indicators of mathematics teachers' knowledge in Table 1. This data coding phase constituted a pivotal component of data condensation. In displaying the data, we employed the method of describing variability with a conceptually clustered matrix (Miles et al., 2014). In this case, each participant's condensed teaching practice and interview were placed in the table so that the fulfilment of the indicators of teacher knowledge could be easily identified. Based on the matrix, conclusions regarding each teacher's profile of TPACK were drawn and verified. Investigator triangulation was carried out to verify the conclusions (Rothbaeur, 2008). All authors actively participated in both data collection and the verification process, ensuring the attainment of a consensus on the conclusions.

**Table 1**  
*Indicators of Mathematics Teacher Knowledge*

Teacher Knowledge	Indicator Description
<i>Technological Knowledge (TK)</i>	<ol style="list-style-type: none"><li>1. The teacher has knowledge related to technology and can teach students to use technology in the form of Google Classroom, zoom, and email.</li><li>2. The teacher can operate and utilize technology.</li></ol>

Teacher Knowledge	Indicator Description
<i>Pedagogical Knowledge (PK)</i>	<ol style="list-style-type: none"> <li>3. The teacher can integrate the use of technology for student learning.</li> <li>4. The teacher can download and install various software developments.</li> <li>1. The teacher submits the learning objectives that must be achieved at the beginning of learning.</li> <li>2. The teacher employs mathematics learning strategies such as inquiry and problem-solving in delivering set content adapted to conditions (online/offline).</li> <li>3. The teacher can determine the learning method according to students' characteristics and feedback.</li> <li>4. The teacher carries out learning activities according to the lesson plan that has been designed.</li> <li>1. The teacher understands the prerequisite material to be able to study set material.</li> <li>2. The teacher can explain the concept of the material sufficiently.</li> <li>3. The teacher has in-depth knowledge of the taught learning materials.</li> <li>4. The teacher presents the content in detail and systematically.</li> <li>5. The teacher summarizes the lessons learned in each meeting.</li> <li>6. The teacher assigns a formative test at the end of the sub-material.</li> <li>7. The teacher provides opportunities for students to build their understanding of the set material and present Venn diagrams to draw a set or several interconnected sets to facilitate students' understanding of the set.</li> <li>8. The teacher makes sets of questions related to contextual problems.</li> </ol>
<i>Content Knowledge (CK)</i>	<ol style="list-style-type: none"> <li>1. The teacher uses the right technology, for example, <i>software, PowerPoint, and Zoom</i>, in teaching set material that is adapted to conditions (online/offline)</li> <li>2. The teacher uses video technology to demonstrate specific concepts according to the set material.</li> <li>3. The teacher uses technology to sort set material, deliver class/online material, and make teaching materials accessible to students.</li> <li>1. The teacher scaffolds students in the relationship between the concepts of the set material being taught and when students have difficulty answering the questions.</li> <li>2. The teacher becomes an interactive and fun online/classroom group learning facilitator.</li> <li>3. The teacher overcomes students' misconceptions regarding the set material.</li> <li>4. The teacher develops materials that are tailored to students' abilities.</li> <li>5. The teacher provides practice questions according to students' abilities</li> <li>6. The teacher implements learning strategies that are tailored to the level of depth and difficulty of the set material</li> </ol>
<i>Technological Content Knowledge (TCK)</i>	<ol style="list-style-type: none"> <li>1. The teacher utilizes technology in managing classes both online / in class.</li> <li>2. The teacher actively involves students in using technology in learning.</li> </ol>
<i>Pedagogical Content Knowledge (PCK)</i>	<ol style="list-style-type: none"> <li>1. The teacher utilizes technology in learning assessment.</li> <li>2. The teacher uses technology effectively to make online collections more interesting.</li> <li>3. The teacher accommodates students' assignments using technology.</li> </ol>
<i>Technological Pedagogical Knowledge (TPK)</i>	
<i>Technological Pedagogical Content Knowledge (TPACK)</i>	

Adapted from Smith & Zelkowski (2022) and Handal et al. (2013)

## **Results and Discussions**

This part displays each participant's work on the task-based interview, learning practice interview, and classroom observation, indicating their technological knowledge, pedagogical knowledge, content knowledge, technological content knowledge, technological pedagogical knowledge, pedagogical content knowledge, and technological pedagogical content knowledge. We then interpret the data to formulate the present study's findings, as summarized in Table 1.

### **Technological Knowledge**

Teachers' knowledge and skills in properly utilizing a particular technology can be displayed in Table 2.

**Table 2**

*Teachers' Technological Knowledge*

Novice Teacher	Technological knowledge
The uncertified teacher	<p>She utilizes projectors and laptops and delivers set material using PowerPoint or Microsoft OneNote in face-to-face and virtual learning (TK 1 and TK 2).</p> <p>She asks her students to submit assignments using technology such as email, Google Forms, and Google Classroom (TK 3).</p>
The certified teacher	<p>She employs effective technology for online learning; however, in offline mode, she needs more classroom resources (TK 1 and TK 2).</p> <p>She asks her students to submit assignments using technology such as email, Google Forms, and Google Classroom (TK 3).</p>

Table 2 indicates that both teachers could utilize technology in virtual learning. These include knowledge and skill regarding operating technology, integrating technology in learning, participating in learning development software training and downloading and installing programs/applications. The uncertified teacher demonstrated sound technological knowledge in online and offline learning. The certified teacher used printed books and whiteboards in offline learning mode because of the school's limited learning facilities. These results corroborate prior studies (Kim, 2018; Mailizar & Fan, 2020; Patahuddin et al., 2016). For instance, Mailizar and his colleague note that the participants' knowledge of computers/laptops was higher than their knowledge of tablets/handheld devices, which is higher than their knowledge about graphing calculators. It is not surprising that teachers perceived their knowledge of computers/laptops to be high due to the fact that they need to use this tool in daily life.

### **Pedagogical Knowledge**

In this section, we present teachers' knowledge about the process and practices of teaching set material.

Table 3

*Teachers' Pedagogical Knowledge*

Novice Teacher	Pedagogical knowledge
The uncertified teacher	<p>She conveys learning objectives and can use learning methods adapted to student characteristics (<i>observation results</i>).</p> <p>She employs contextual learning depending on the material's difficulty level and can be linked to actual objects around students.</p>
The certified teacher	<p>She conveys learning objectives and can use learning methods adapted to student characteristics (<i>observation results</i>).</p> <p>She utilizes more contextual learning strategies because they can be connected with real objects around students and provides many examples of questions and explanations that are as simple as possible so students can better understand.</p>

Table 3 depicts that both uncertified and certified teachers conveyed learning objectives and strategies and carried out learning activities according to lesson plans. For learning methods, the uncertified teacher employed conventional and question-and-answer methods, while the certified teacher used discussion, expository, and question-and-answer methods in delivering set content. The uncertified teacher explained the definition and symbols of the set, the element and non-element of the set, empty and zero sets, and their notations. She understood the universal set, mentioned its element, and was able to identify the properties of set operations (PK1) using contextual learning strategies, conventional methods, and question-and-answer methods during the learning process according to the lesson plan that has been designed (PK2, PK3, and PK4).

From the interview, we obtained that the uncertified teacher used contextual learning strategies depending on the material's difficulty level and could be related to objects around students. From the results of the exposure related to observations and interviews of learning practices, it can be concluded that both teachers have excellent pedagogical approaches in conveying learning objectives and strategies (PK1 and PK2), as well as carrying out learning activities according to the lesson plan (PK4), only for the learning method that is applied one of them still using the conventional method (PK3). These findings resonate with previous studies (Helliwell & Ng, 2022; Leong et al., 2015; Nur'aini & Pagiling, 2020).

**Content Knowledge**

We display teacher knowledge of a set content to be taught, which demands understanding core principles, facts, theories, procedures, and set concepts from classroom practices and task-based interviews in Table 4 and Table 5, respectively.

Table 4

*Teachers' Content Knowledge*

Novice Teacher	Content knowledge
The uncertified teacher	Both teachers explain prerequisite knowledge, such as integers, algebraic forms, and linear equations with a single variable. Subsequently, they can define set

Novice Teacher	Content knowledge
The certified teacher	concepts well and systematically, have in-depth knowledge of sets, provide opportunities for students to build their understanding, present Diagram Venn to describe relationships between sets to help students understand, and relate the questions to contextual problems.

Table 4 depicts that both teachers could distinguish examples included in the set and those not and could conclude the definition of the set. Moreover, they could distinguish and explain ways of expressing sets, including tabulation, conditional, and description methods. They explained each set, which is a subset of itself, and the things that must be considered in describing the Venn diagram.

In the third problem, the teachers could also work on and explain word problems or those related to contextual problems. Both uncertified and certified teachers delivered prerequisite material, explained the set material in detail and systematically, gave formative tests to students, and answered task-based interviews from the seven question indicators that the researcher assigned. In the material's concluding section, uncertified and certified teachers did not engage students because of time constraints. For design tasks, the uncertified teacher faced difficulty making minimum competency assessments and higher-order thinking problems and had yet to teach students about the properties of sets, commutative, associative, and distributive. In contrast, the certified teacher had no difficulties because she associated tasks with contextual problems. These findings align with prior studies (Budiarto et al., 2021; Carrillo-Yañez et al., 2018; Pagiling & Nur'aini, 2022).

Table 5

*Content Knowledge of Teachers in Solving Set Problems*

The uncertified teacher	The certified teacher
<b>Definition of sets and members of the set</b> Both teachers are able to understand and solve the set problems well. Moreover, they are able to distinguish examples that are and are not included in the set and are able to conclude the definition/understanding of the set.	
<b>Declaration of sets</b> In the second and fourth questions, she was able to distinguish and understand the ways of declaring a set, including mentioning its elements, stating its properties, and notating the set. For the third question, S1 was able to define prime numbers set correctly.	In the first, third, and fourth questions, the teacher can understand, distinguish, and explain ways of expressing sets, including tabulation, conditional, and description methods. For the second question, she can define prime numbers set accurately.

  

Finite and Infinite Sets	
She still needed to improve in answering questions related to the set of mathematics teachers in Merauke in the first question. She answered correctly after the researchers discussed the scope of finite and infinite sets. She can understand, answer, and conclude correctly for the third and fourth questions regarding whole numbers, definitions of finite and infinite sets, and the union of two sets.	In the first question, she explained a finite set, referring to the set of mathematics teachers in Merauke. She can understand, answer, and conclude correctly for the second, third, and fourth questions regarding whole numbers, definitions of finite and infinite sets, and the union of two sets.

The uncertified teacher	The certified teacher
<b>Subsets, Venn diagrams, and empty sets</b> In the first and second questions, both teachers can explain each set, which is a subset of itself, and the things that need to be considered in describing the Venn diagram. In the third problem, they can also solve and explain word problems or those related to contextual problems well. In response to the fourth question, she explained how empty sets can be included in subsets, but she could not provide a detailed explanation.	
<b>The intersection and union of the set</b> Both teachers can accurately solve and explain the intersection and union of set problems in the first and second questions.	
<b>Complement and difference of sets</b> In the first question, both teachers answered the complement problem and explained the difference between complement and difference given in the second question.	
<b>Properties of sets</b> Both teachers are able to explain the properties of the set by giving each example problem.	

## Technological Content Knowledge (TCK)

In this section, we describe teachers' knowledge of which technology and content interact in effective teaching, including teachers' understanding of how technology can change set content.

Table 6

### Teachers' Technological Content Knowledge

Novice Teacher	Technological content knowledge
The uncertified teacher	The teacher utilizes the appropriate technology, such as PowerPoint, a projector, a laptop, a whiteboard, and printed books.
The certified teacher	She uses Zoom, classroom, and Google Forms during online learning and does not use technology during offline learning due to limited facilities; consequently, she only uses whiteboards and printed books to deliver the material.

Table 6 illustrates that teachers who have yet to be certified could use technology as a teaching tool in the learning process. Meanwhile, certified teachers could use technology in the online learning process. She only employed printed books and blackboards for offline learning because the school provides no power outlets or projectors. Meanwhile, for teaching materials in *e-modules*, both certified and certified teachers still need to implement them and only use printed modules distributed directly to students.

Interestingly, based on the observations and interviews, TCK's abilities show that an uncertified teacher can utilize the appropriate technology such as PowerPoint, projector, laptop, whiteboard, and printed books during offline settings and Zoom and OneNote during online learning. In contrast, certified teachers use Zoom, Google Classroom, and Google Forms during online learning and do not use technology during offline learning due to limited facilities in power sockets and projectors. Hence, she only used whiteboards and printed books to convey the material. For learning videos, the uncertified teacher produces learning

videos and uploads them on the school's YouTube account so that the videos are relevant for students to watch when studying the set material. In contrast, the certified teacher usually enquires students to watch videos on YouTube and sometimes sends links to learning videos uploaded to personal YouTube accounts and video links distributed to WhatsApp groups. Then, for teaching materials, the uncertified teacher does not use e-modules but only regular modules or printed books, which are distributed directly to students. Thus, we can infer that the uncertified teacher's ability outperforms the certified teacher in terms of technological pedagogical knowledge.

### **Pedagogical Content Knowledge (PCK)**

We display teacher knowledge of how particular pedagogical approaches are appropriated to teaching set content in Table 7.

Table 7

*Teachers' Pedagogical Content Knowledge*

Novice Teacher	Pedagogical content knowledge
The uncertified teacher	Both teachers provide gradual assistance to students with problems mastering the assigned content, acting as interactive and entertaining online and offline learning facilitators. Then, both teachers can overcome common student misconceptions by using more explicit language to address misunderstandings, providing emphasis, instructions, and practice problems.
The certified teacher	

Table 7 shows a teacher who has not been certified and who is certified scaffolded students in the relationship between the concepts of the set material when students had difficulty answering the questions given, were able to become interactive and fun facilitators, overcame student misconceptions as well as developed material and provide practice questions according to students' abilities. To apply learning strategies adapted to the level of depth of material, the uncertified teachers employed contextual techniques for all subsections of the set material. It is an essential pedagogical approach that involves noticing how students responded during the lesson phases and how the lesson structure promoted and accommodated student learning. In other words, teachers can reinforce the point of choosing and selecting students to share their strategies (Livy & Downton, 2018). Moreover, as described by Lee and Lee (2023), teachers should employ differentiated instruction to accommodate diverse learning styles and levels of prior knowledge and support struggling students. In contrast, certified teachers create new tasks if the competency test is difficult for students and master building and answering questions with students.

### **Technological Pedagogical Knowledge (TPK)**

In this section, we describe both teachers' knowledge of how to use various technologies with distinct pedagogical approaches. It involves recognizing and utilizing the affordances of technologies and choosing pedagogical approaches that fit particular technologies and vice versa.

Table 8

*Teachers' Technological Pedagogical Knowledge*

Novice Teacher	Technological pedagogical knowledge
The uncertified teacher	Unable to utilize technology during offline learning.
The certified teacher	Capable of integrating technology into offline and online learning activities

Table 8 depicts that a teacher who has not been certified could use technology to manage classes. In contrast, a certified teacher utilizes technology to manage and organize the classroom during online learning. However, the teacher has not incorporated technology during offline learning due to limited learning facilities. To actively engage students in technology, the two teachers still need to implement it in grade 7 due to their need for more technical knowledge and skills in fostering student engagement. These findings align with prior studies (Jansen et al., 2023; R. C. Smith et al., 2017), which point out that teachers need school support in incorporating technology into their practice.

**Technological Pedagogical Content Knowledge (TPACK)**

We describe teachers' knowledge that is more than the sum of its three components (content, pedagogy, and technology) in Table 9. It is the knowledge of the basis for effective teaching with the application of technology. It requires an understanding of pedagogical techniques that use technologies in constructive ways to assist students in overcoming difficulties and learning set content effectively.

Table 9

*Teachers' Technological Pedagogical Knowledge*

Novice Teacher	Technological pedagogical content knowledge
The uncertified teacher	The uncertified teacher employs technology in assessing student learning but still uses manual modules.
The certified teacher	The certified teacher uses <i>Quizizz</i> and <i>Google Forms</i> for assessment during online learning.

The teacher who has yet to be certified has yet to utilize technology in learning assessment. Meanwhile, due to limited facilities, the certified teacher needs to be more optimal in using technology in Quizizz in learning evaluations. For making *e-module* teaching materials and presenting PowerPoint assignments, the two teachers have yet to be able to apply them to learning practices.

The uncertified teachers used technology in learning assessment but still used manual modules, and the use of Google Forms and e-modules began to be implemented in grade 8. In line with research conducted by Mailizar and Fan (2020) examining teacher knowledge related to ICT and its application in the classroom, it was found that mathematics teachers needed more knowledge about ICT and strategies for using ICT in teaching. Meanwhile, the certified teachers used Quizizz and Google Forms to assess online learning time, provide questions directly, collect them, and give assignments during offline learning.

The results of these observations align well with a study by Parinata and Puspaningtyas (2021), which explains that the use of Google Forms is very suitable for collecting opinions

from people who are far apart, managing the event or school registration via the Internet, collecting data, taking quizzes, and reviewing more straightforward questions. Moreover, this observation, in line with the findings of Kim's study (2018), showed that most teachers view technology as a tool that helps to teach (for example, providing teaching aids or creating teaching materials) rather than increasing student collaboration, creativity, and active engagement.

The uncertified teacher's knowledge of technology, content, and pedagogy has yet to be maximized in integrating technology since she only used online and offline learning modules. In contrast, certified teachers could use technology in the form of the quiz during online learning and give assignments directly during offline learning.

In this case, there are differences in the knowledge of technology, content, and pedagogics for 7<sup>th</sup>-grade mathematics teachers when viewed from the perspectives of novice mathematics teachers who have not or have been certified. Teachers who are not qualified cannot use technology in assessment, while certified teachers could apply Quizizz during online learning.

These findings are consistent with previous studies presented by Stein et al. (2020), Yu et al. (2022), and Gurevich et al. (2017), which state that although teachers use different technological tools and try to adapt them in their teaching, there is a significant discrepancy between the existing teaching material and new technological tools.

This study involved only two mathematics teachers; therefore, different results might be achieved if a similar study involved many teachers with varying years of teaching, genders, socio-economic status, and subject matter contexts. However, the findings of this study provide an insightful lens to understand novice mathematics teachers' TPACK in teaching the set concepts. In the context of the teacher's professional development, which comprises training with diverse levels of mathematics proficiency, some teachers could reach optimal proficiency. In this case, further research is necessary to fully understand mathematics teachers' TPACK with various years of teaching. The profiles will be an entry point for the government, especially the Indonesian Ministry of Education and Culture and educational institutions, to conduct systemic and well-structured workshops that assist the teacher in developing their TPACK.

## **Conclusion**

The TPACK ability of novice mathematics teachers shows that the TPACK ability of certified teachers is distinct from that of uncertified teachers. In terms of technology knowledge, the uncertified teacher could utilize technology well during learning. Meanwhile, certified teachers could use sound technology during online learning, but they still needed to apply technology during the offline learning process due to limited learning facilities in the classroom. In pedagogical knowledge, teachers who have yet to be certified convey the learning objectives at the beginning of the material. As for learning methods/strategies, the uncertified teacher only used conventional and question-and-answer methods, while certified teachers used expository, discussion, and question-and-answer methods under the lesson plans. In terms of content knowledge, teachers who have and have yet to be certified have an in-depth understanding of the material. In the CK aspect of the task-based interview section,

the uncertified teachers still needed to improve in answering one of the problems. In contrast, certified teachers could answer all questions from the eight indicators. The implication of this study is to encourage TPACK learning and improvement; it is essential to offer specific projects and ICT intervention schemes that centre on pedagogy. In addition, the education stakeholder should set standards for TPACK level before obtaining qualified teacher status and create a shared space where mathematics teachers, mathematics education researchers, policymakers, and digital technology designers can communicate and corroborate.

## References

Abbitt, J. T. (2011a). An investigation of the relationship between self-efficacy beliefs about technology integration and Technological Pedagogical Content Knowledge (TPACK) among Pre-service Teachers. *Journal of Digital Learning in Teacher Education*, 27(4), 134–143. <https://doi.org/10.1080/21532974.2011.10784670>

Abbitt, J. T. (2011b). Measuring technological pedagogical content knowledge in pre-service teacher education: A review of current methods and instruments. *Journal of Research on Technology in Education*, 43(4), 281–300. <https://doi.org/10.1080/15391523.2011.10782573>

Akyuz, D. (2018). Measuring technological pedagogical content knowledge (TPACK) through performance assessment. *Computers and Education*, 125(May 2017), 212–225. <https://doi.org/10.1016/j.compedu.2018.06.012>

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers and Education*, 52(1), 154–168. <https://doi.org/10.1016/j.compedu.2008.07.006>

Budiarto, M. T., Fuad, Y., & Sahidin, L. (2021). Teacher's specialized content knowledge on the concept of square: A vignette approach. *Jurnal Pendidikan Matematika*, 15(1), 1–22. <https://doi.org/10.22342/jpm.15.1.11653.1-22>

Carrillo-Yáñez, J., Climent, N., Montes, M., Contreras, L. C., Flores-Medrano, E., Escudero-Ávila, D., Vasco, D., Rojas, N., Flores, P., Aguilar-González, Á., Ribeiro, M., & Muñoz-Catalán, M. C. (2018). The mathematics teacher's specialised knowledge (MTSK) model\*. *Research in Mathematics Education*, 20(3), 236–253. <https://doi.org/10.1080/14794802.2018.1479981>

Chai, C. S., Chin, C. K., Koh, J. H. L., & Tan, C. L. (2013). Exploring Singaporean Chinese language teachers' technological pedagogical content knowledge and its relationship to the teachers' pedagogical beliefs. *Asia-Pacific Education Researcher*, 22(4), 657–666. <https://doi.org/10.1007/s40299-013-0071-3>

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2016). A review of the quantitative measures of technological pedagogical content knowledge (TPACK). In M. C. Herring, M. J. Koehler, & P. Mishra (Eds.), *Handbook of Technological Pedagogical Content Knowledge (TPACK) for Educators* (2nd ed., pp. 87–106). Routledge. <https://doi.org/10.4324/9781315771328>

Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers and Education*, 57(3), 1953–1960. <https://doi.org/10.1016/j.compedu.2011.04.010>

Gurevich, I., Stein, H., & Gorev, D. (2017). Tracking professional development of novice teachers when integrating technology in teaching mathematics. *Computers in the Schools*, 34(4), 267–283. <https://doi.org/10.1080/07380569.2017.1387470>

Handal, B., Campbell, C., Cavanagh, M., Petocz, P., & Kelly, N. (2013). Technological pedagogical content knowledge of secondary mathematics teachers. *Contemporary Issues in Technology and Teacher Education*, 13(1), 22–40. <http://www.citejournal.org/vol13/iss1/mathematics/article1.cfm>

Harris, J., Grandgenett, N., & Hofer, M. (2010). Testing a TPACK-based technology integration assessment rubric. *Teacher Education and Professional Development Commons*, 3833–3840. <http://digitalcommons.unomaha.edu/cgi/viewcontent.cgi?article=1014&context=tedfacp>

Helliwell, T., & Ng, O. L. (2022). Imagining possibilities: innovating mathematics (teacher) education for sustainable futures. *Research in Mathematics Education*, 24(2), 128–149. <https://doi.org/10.1080/14794802.2022.2079553>

Jansen, A., Curtis, K., Mohammad, A., Cullicott, C. E., Smith, E. P., & Middleton, J. A. (2023). Secondary mathematics teachers' descriptions of student engagement. *Educational Studies in Mathematics*, 0123456789. <https://doi.org/10.1007/s10649-023-10228-x>

Kartowagiran, B. (2011). Kinerja guru profesional (guru pasca sertifikasi). *Cakrawala Pendidikan*, 30(3), 463–473.

Kim, S. (2018). Technological, Pedagogical, and Content Knowledge (TPACK) and beliefs of pre-service secondary mathematics teachers: Examining the relationships. *EURASIA Journal of Mathematics, Science and Technology Education*, 14(10). <https://doi.org/10.29333/ejmste/93179>

Koh, J. H. L. (2019). Articulating teachers' creation of Technological Pedagogical Mathematical Knowledge (TPMK) for supporting mathematical inquiry with authentic problems. *International Journal of Science and Mathematics Education*, 17(6), 1195–1212. <https://doi.org/10.1007/s10763-018-9914-y>

Koh, J. H. L., & Chai, C. S. (2016). Seven design frames that teachers use when considering technological pedagogical content knowledge (TPACK). *Computers and Education*, 102, 244–257. <https://doi.org/10.1016/j.compedu.2016.09.003>

Lachner, A., Fabian, A., Franke, U., Preiß, J., Jacob, L., Führer, C., Küchler, U., Paravicini, W., Randler, C., & Thomas, P. (2021). Fostering pre-service teachers' technological pedagogical content knowledge (TPACK): A quasi-experimental field study. *Computers and Education*, 174(February). <https://doi.org/10.1016/j.compedu.2021.104304>

Lee, M. Y., & Lee, J. E. (2023). The relationship between pre-service elementary teachers' solutions to a pattern generalization problem and difficulties they anticipate in teaching it. *Journal of Mathematical Behavior*, 69(May 2022). <https://doi.org/10.1016/j.jmathb.2023.101046>

Leong, K. E., Meng, C. C., & Abdul Rahim, S. S. (2015). Understanding Malaysian pre-service teachers mathematical content knowledge and pedagogical content knowledge. *Eurasia Journal of Mathematics, Science and Technology Education*, 11(2), 363–370. <https://doi.org/10.12973/eurasia.2015.1346a>

Livy, S., & Downton, A. (2018). Exploring experiences for assisting primary pre-service teachers to extend their knowledge of student strategies and reasoning. *Journal of Mathematical Behavior*, 51(November 2016), 150–160. <https://doi.org/10.1016/j.jmathb.2017.11.004>

Lyublinskaya, I., & Kaplon-Schilis, A. (2022). Analysis of differences in the levels of TPACK: Unpacking performance indicators in the TPACK levels rubric. *Education Sciences*, 12(2). <https://doi.org/10.3390/educsci12020079>

Lyublinskaya, I., & Tournaki, N. (2011). The effects of teacher content authoring on tpack and on student achievement in algebra: Research on instruction with the TI-Nspire™ Handheld. In R. N. Ronau, C. R. Rakes, & M. L. Niess (Eds.), *Educational Technology, Teacher Knowledge, and Classroom Impact: A Research Handbook on Framework and Approaches* (pp. 295–322). IGI Global. <https://doi.org/10.4018/978-1-60960-750-0>

Mailizar, M., & Fan, L. (2020). Indonesian teachers' knowledge of ICT and the use of ICT in secondary mathematics teaching. *Eurasia Journal of Mathematics, Science and Technology Education*, 16(1), 1–13. <https://doi.org/10.29333/ejmste/110352>

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). SAGE Publications, Inc.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017–1054. <https://doi.org/10.1177/016146810610800610>

Niess, M. L. (2013). Central component descriptors for levels of technological pedagogical content knowledge. *Journal of Educational Computing Research*, 48(2), 173–198. <https://doi.org/10.2190/EC.48.2.d>

Njiku, J. (2023). Assessing the development of mathematics teachers TPACK through an observation rubric. *Education and Information Technologies*. <https://doi.org/10.1007/s10639-023-11901-7>

Nur'aini, K. D., & Pagiling, S. L. (2020). Analisis pedagogical content knowledge guru matematika sekolah menengah pertama ditinjau dari segi gender. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, 9(4), 1036. <https://doi.org/10.24127/ajpm.v9i4.3171>

Oner, D. (2020). A virtual internship for developing technological pedagogical content knowledge. *Australasian Journal of Educational Technology*, 36(2), 27–42. <https://doi.org/10.14742/ajet.5192>

Pagiling, S. L., & Nur'aini, K. D. (2022). Specialized content knowledge lower secondary school teachers on quadrilaterals. *PYTHAGORAS Jurnal Pendidikan Matematika*, 17(1), 333–345. <https://doi.org/10.21831/pythagoras.v17i1.42446>

Parinata, D., & Puspaningtyas, N. D. (2021). Optimalisasi penggunaan google form terhadap pembelajaran matematika. *Mathema: Jurnal Pendidikan Matematika*, 3(1), 56–65.

Patahuddin, S. M., Lowrie, T., & Dalgarno, B. (2016). Analysing mathematics teachers' TPACK through observation of practice. *Asia-Pacific Education Researcher*, 25(5–6), 863–872. <https://doi.org/10.1007/s40299-016-0305-2>

Rakes, C. R., Stites, M. L., Ronau, R. N., Bush, S. B., Fisher, M. H., Safi, F., Desai, S., Schmidt, A., Andreasen, J. B., Saderholm, J., Amick, L., Mohr-Schroeder, M. J., & Viera, J. (2022). Teaching mathematics with technology: TPACK and effective teaching practices. *Education Sciences*, 12(2). <https://doi.org/10.3390/educsci12020133>

Rothbaeur, P. M. (2008). Triangulation. In L. M. Given (Ed.), *The SAGE Encyclopedia of Qualitative Research Methods* (pp. 892–894). SAGE Publications, Inc.

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (Track): The development and validation of an assessment instrument for pre-service teachers. *Journal of Research on Technology in Education*, 42(2), 123–149. <https://doi.org/10.1080/15391523.2009.10782544>

Smith, P. G., & Zelkowski, J. (2022). Validating a TPACK instrument for 7–12 mathematics in-service middle and high school teachers in the United States. *Journal of Research on Technology in Education*, 0(0), 1–19. <https://doi.org/10.1080/15391523.2022.2048145>

Smith, R. C., Shin, D., & Kim, S. (2017). Prospective and current secondary mathematics teachers' criteria for evaluating mathematical cognitive technologies. *International Journal of Mathematical Education in Science and Technology*, 48(5), 659–681. <https://doi.org/10.1080/0020739X.2016.1264635>

Stein, H., Gurevich, I., & Gorev, D. (2020). Integration of technology by novice mathematics teachers – what facilitates such integration and what makes it difficult? *Education and Information Technologies*, 25(1), 141–161. <https://doi.org/10.1007/s10639-019-09950-y>

Stoilescu, D. (2015). A critical examination of the technological pedagogical content knowledge framework: Secondary school mathematics teachers integrating technology. *Journal of Educational Computing Research*, 52(4), 514–547. <https://doi.org/10.1177/0735633115572285>

Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge - A review of the literature. *Journal of Computer Assisted Learning*, 29(2), 109–121. <https://doi.org/10.1111/j.1365-2729.2012.00487.x>

Yin, R. K. (2018). *Case study research and applications: Design and methods* (Sixth). SAGE Publications, Inc.

Yu, B., Smith, W. C., & Cao, Y. (2022). The relationship between propositional teacher knowledge and classroom teaching practice: the case of Chinese novice mathematics teachers. *Asia Pacific Journal of Education*, 00(00), 1–17. <https://doi.org/10.1080/02188791.2022.2096570>

Zelkowski, J., Gleason, J., Cox, D. C., & Bismarck, S. (2013). Developing and validating a reliable TPACK instrument for secondary mathematics pre-service teachers. *Journal of Research on Technology in Education*, 46(2), 173–206. <https://doi.org/10.1080/15391523.2013.10782618>