Southeast Asia Mathematics Education Journal
Volume 14, No 2 (2024)

TPACK Skills of Pre-service Teachers in Technology Integration: A Study in Microteaching Class

Pipit Firmanti[1], Fauzi Yuberta[2], Yoppy Wahyu Purnomo[3],
Fery Muhamad Firdaus[4],
[1,2,3]*Universitas Negeri Yogyakarta, Indonesia*
[4]*Sekolah Tinggi Pertanahan Nasional, Indonesia*
[1]*pipitfirmanti.2024@student.uny.ac.id*

Abstract

The integration of technology in mathematics education is a tangible manifestation of the rapid development of the times. Therefore, teachers must use technological devices to ensure students stay competitive in the global arena. This study aims to describe the distribution of TPACK skills among pre-service mathematics teachers and monitor their development during their microteaching experiences. This research is a qualitative descriptive study. The participants in the study were eleven students at UIN Sjech M Djamil Djambek Bukittinggi who were taking a microteaching course in the even semester of 2023/2024. The instruments used were the TPACK questionnaire and observation sheets. Based on the observation, in the first session, some subjects were unable to use or operate the software they had downloaded, and many quiz applications encountered problems because they could not be opened. The challenges faced included paid software and issues operating the software on different laptops. It is suspected that one student did not attend because she was not prepared to present. Additionally, the development of skills for each TPACK aspect generally showed improvement in subsequent sessions. The subjects generally used presentation slide applications such as Microsoft PowerPoint™ and Canva™ to explain the material and conducted evaluations by giving quizzes through applications such as Quizizz™, Kahoot™, Wordwall™, and Bamboozle™. The results show that the students' skills based on the TPACK Questionnare were at a moderate level with an average score of 3.38. However, there are differences between the results of the questionnaire and the observations carried out. For instance, in the aspect of Technological Pedagogical Knowledge especially for item "I can utilize available technologies as a learning aid". The questionnaire showed a high rating 3.63. On the other hand, observations indicate that students' abilities are still lacking, indicating that students have much to learn, especially in the use of technology in the learning process to enhance the learning environment in mathematics

Keywords: *TPACK, technology integratu, mathematics education*

Introduction

Technological advancements impact all aspects of life, including education. Various types of technology can be used as tools to assist teachers in delivering instructional material. Technology has become integral to modern education, including mathematics instruction. Moreover, a strategy is needed to improve learning outcomes and provide a systematic support to the instructional work of teachers, such as the Italian LSA approach namely ‘the integration of technologies in teaching with Learning Solutions Approach (Gentile & Pisanu, 2013). In addition, the approach conducted by Jenita et al. (2023) shows an increase in motivation and enthusiasm for learning and a stronger commitment to the development of technology-based education. (Jenita et al., 2023). In other words, technology integrated into the learning process is expected to help develop conceptual understanding of student (Putrawangsa & Hasanah, 2018), so that the knowledge acquired is cohesive and not fragmented. For instance, applying Computer-Based Mathematics Learning significantly affects students' mathematical abilities (Tamur et al., 2023). Subsequently, the use of technology has become a daily habit for education students, reflecting the significant integration of technology into their learning experience (Meisuri et al., 2023).

Pre-service mathematics teachers must have a holistic skill set, including integrating technology effectively. Effective technology integration should not be facilitated as a stand-alone event, focusing solely on technical skills (Tondeur et al., 2017). The TPACK framework describes the kinds of knowledge that teachers need in order to teach with technology, and the complex ways in which these bodies of knowledge interact with one another (Koehler et al., 2013). In other words, this framework integrates technological knowledge, content, and pedagogy within specific teaching and learning contexts. TPACK stands for Technological Pedagogical Content Knowledge, which refers to three dimensions: technology (T), pedagogy (P), and content (C) knowledge. Nowadays, TPACK has become popular for integrating ICT mathematics education.

This framework is crucial for developing the pedagogical competencies of 21st-century teachers. The traditional classroom teaching space is now designed as a technology-based learning environment to create an effective students learning process.(Oktaviana & Yudha, 2022). The TPACK framework provides a map for understanding how to effectively integrate technology and instructional strategies into the content effectively (Rohmitawati, 2018).

More specifically, TPACK can be described as follows: (i) Technological Knowledge (T): Knowledge about relevant technology and how to use it effectively in a learning context, (ii) Pedagogical Knowledge (P): Knowledge about principles and strategies of effective teaching to help students understand the subject matter, (iii) Content Knowledge (C): Knowledge about the specific subject matter to be taught(Schmidt et al., 2014).Finally, TPACK is the intersection of all the three knowledge areas (TK, CK, and PK) (Omoso & Odindo, 2020). Teachers are able to use technology appropriately and effectively to support student learning in understanding mathematical content (or other subject areas). Moreover, teachers are also able to develop innovative and adaptive teaching strategies tailored to their needs and learning contexts. This is in line with research conducted by (Amrina et al., 2022), which analyzed TPACK in relation to the ability to develop online mathematics teaching materials among prospective primary school teachers. The study found that prospective teachers with high TPACK abilities have a positive influence on their ability to create online mathematics teaching materials.

TPACK indicators also emphasize the creation of meaningful learning experiences to enhance students' conceptual understanding and develop their intuition in mathematics (Putrawangsa & Hasanah, 2018). Although students have received theoretical foundations in their educational curriculum, practical implementation in teaching still requires further development. Additionally, (Sholeh & Efendi, 2023) state that teachers need to identify and address learning challenges by integrating appropriate technology into the teaching process. The ability of pre-service teacher students to integrate technology can also be observed through TPACK components in microteaching classes.

Microteaching is a program that is included in the curriculum of the education department (Saliman et al., 2017; Satriawati et al., 2022) to strengthen pre-service teacher's teaching skills (Mukuka & Alex, 2024; Blegur et al., 2023). In addition, students can also use various learning methods in this course (Siregar, 2021). Microteaching is an effective method for observing and improving teaching practices on a smaller scale. In general, this course is taken by pre-service teachers in their third year and is worth two to four credits. UIN Sjech M Djamil Djambek Bukittinggi, for instance, has four credits. Through microteaching, pre-service teachers can test and enhance their ability to integrate technology into mathematics instruction, thereby optimizing the learning process for the future.

There is a research gap concerning how to measure primary mathematics teachers' TPACK, how to design a TPACK instrument that includes contextual factors, and how to develop TPACK-oriented teacher training programs for primary mathematics teachers (Li et al., 2024). Meanwhile, research conducted by Faradilla & Putra (2024) shows that pre-service mathematics teachers tend to have TPACK at a moderate level. However, it does not provide detailed information on students' abilities in each aspect of TPACK. In addition, some research conducted on the TPACK abilities of prospective teacher students through micro teaching only used three indicators: Technological Knowledge, Content Knowledge and Pedagogical Knowledge. (Farida & Kusumawati, 2024; Satriawati et al., 2022). Therefore, the research is needed to describe TPACK capabilities using questionnaire and direct observations with full indicators.

Based on the above description, the research problem in this study is: What is the distribution level of TPACK abilities among pre-service mathematics teachers in integrating technology during microteaching classes? Additionally, this study aims to describe the distribution level of TPACK abilities among pre-service mathematics teachers and monitor their development during microteaching courses.

Methodology

This study is a type of qualitative descriptive research. The research subjects consist of one microteaching class, Class F, Academic Year 2024/2025, which includes eleven students. The sampling of Class F was done because the students have an average level of mathematical ability that is already good, allowing the subjects to be guided in using technology in their teaching practice. The instruments used are TPACK questionnaires and observation sheets. An additional way to measure TPACK is through observations of teacher-enacted lessons. The seven TPACK components and their aspects in more detail can be seen in Table 1.

Table 1. TPACK Instrument for 21st Century Skills (Herizal et al., 2022)

Component	Aspect
Technological Knowledge (TK)	Understanding various technological elements, including the use of technology, technological developments, and internet-related aspects.
Content Knowledge (CK)	Mastering the facts, concepts, principles, and procedures of a mathematics topic.
Pedagogical Knowledge (PK)	Understanding learning theories, students' cognitive development, and how to apply these in the classroom to support 4C skills.
Pedagogical Content Knowledge (PCK)	Able to relate learning theories to mathematics content that supports 4C skills.
Technological Content Knowledge (TCK)	Able to integrate technology with various mathematics content.
Technological Pedagogical Knowledge (TPK)	Able to integrate technology into lesson planning, teaching implementation, and assessment of mathematics instruction that is appropriate for students.
Technological Pedagogical Content Knowledge (TPCK)	Able to integrate technology effectively into the planning, implementation, and evaluation of instruction to facilitate teaching mathematics content that aligns with students' characteristics.

The questionnaire instrument was adopted from Murtiyasa & Atikah, (2021) and consists of 35 statements covering all aspects of TPACK, with response options including Excellent (5), Good (4), Adequate (3), Inadequate (2), and Very Inadequate (1). This is because the questionnaire has been validated and tested so that each item is valid and reliable. Therefore, the items for each TPACK indicator are clear and detailed. Furthermore, the questionnaire results obtained later for each TPACK indicator will be grouped into five categories with the following interpretations: Very High (4.51 – 5.00), High (3.51 – 4.50), Moderate (2.51 – 3.50), Low (1.51 – 2.50), and Very Low (1.00 – 1.50) (Nuangchalerm, 2020).

The techniques used to collect data during the research are from questionnaires and observation results. Furthermore, the analysis technique uses stages, namely data reduction, data presentation, and drawing conclusions (Sugiyono, 2014).

Subsequently, the research and observations were conducted over 4 sessions. In the first session, tasks related to the application of technology in teaching were assigned (e.g., summarizing material, determining the type of ICT to be used, and specifying the content). In the second session, subjects practiced teaching P1 (initial instruction on the selection of different types of ICT). In the third session, subjects practiced teaching P2 with different material, but the type of technology remained the same. In the fourth session, subjects practiced teaching P3 with different material, but the type of technology remained the same.

Results and Discussion

The Data of TPACK

Subjects were given a TPACK questionnaire to describe their ability to integrate technology. This can be seen from the distributed questionnaires. The initial data of the students can be found in Table 3 below:

Table 2. Student Abilities Based on TPACK

No	Aspect of TPACK	Average Score	n	Category
1	Technological Knowledge (TK)	3.47	11	Moderate
2	Content Knowledge (CK)	3.44	11	Moderate
3	Pedagogical Knowledge (PK)	3.36	11	Moderate
4	Pedagogical Content Knowledge (PCK)	3.31	11	Moderate
5	Technological Content Knowledge (TCK)	3.47	11	Moderate
6	Technological Pedagogical Knowledge (TPK)	3.27	11	Moderate
7	Technological Pedagogical Content Knowledge (TPCK)	3.33	11	Moderate
	The average	3.38	11	Moderate
	Standar deviation	0.075		

Based on Table 3 above, it can be concluded that the students' abilities based on TPACK are in the moderate category, with an average score of 3.38. The highest ability is in the TK category, with a score of 3.47, while the lowest is in the TPK category, with a score of 3.27.

Description of Framework TPACK

Technological Knowledge (3,47/ Moderate Level)

The subjects' ability to understand various technological elements, including the use of technology, technological developments, and internet-related aspects, can be observed from the selection of the types of technology used in teaching. The types of technology used in the teaching process include videos downloaded from YouTube^{TM}/Quipper^{TM} at the beginning of the lesson and PowerPoint^{TM} presentations created with Canva^{TM} to explain the material.

In addition, the mathematics software used includes Maple^{TM}, GeoGebra^{TM}, and Microsoft Mathematics^{TM}. Meanwhile, applications used at the end of the lesson for conducting quizzes include Quizizz^{TM}, Bamboozle^{TM}, Wordwall^{TM}, and Kahoot^{TM}. Some students also created websites containing material, quizzes, and other resources as part of the teaching process. For a clearer view of the types of technology chosen by the subjects, please refer to Table 3 below:

Table 3. Types of Technology Used in Session 1 (P1)

No	Type of Technology	Frequency	Percentage
1	Maple™	1	5.88
2	GeoGebra™	2	11.76
3	Microsoft PowerPoint™	1	5.88
4	Canva™	3	17.65
5	Microsoft Mathematics™	1	5.88
6	Website	1	5.88
7	Video YouTube™	1	5.88
8	Quiziz™	4	23.53
9	Kahoot™	1	5.88
10	Quiz (wordwall™)	1	5.88
11	Bamboozle™	1	5.88
	Total	17	100

In the first session, some subjects were unable to use or operate the software they had downloaded, and many quiz applications encountered problems because they could not be opened. The challenges faced included paid software and issues using the software on different laptops. It is suspected that one student did not attend because the student was not prepared to present. In the subsequent sessions, the students' performance improved compared to the earlier sessions**.** In the final session, the students generally used PowerPoint™ presentations designed with Canva™. Some of them started to use the PowerPoint™ presentations effectively and comfortably.

Content Knowledge (3,44/ Moderate Level)

Before explaining the material, subjects were expected to master the facts, concepts, principles, and procedures of a mathematics topic. However, in practice, there were some concepts that the subjects had not fully grasped. This led to conceptual errors during the explanation of the material. For example, when teaching the topic of Systems of Linear Equations in Two Variables, the subject directly provided example problems using variables x and y, then applied the elimination and substitution methods to find the solutions. The problems were not preceded by contextual or other introductory problems. For a clearer view, please refer to Table 4 below:

Table 4. Description of TPACK Framework Results for the CK Aspect

Subject number	Material Learning	Results of Observation P4
1	Set	Subject understood the definition of a set and she explained to student well.
2	Integral	The subject was aware of the benefits of studying integrals. However, the subject did not understand the definition of integrals, which resulted in difficulty when explaining the material directly, even when providing a definite integral formula.
3	Linear Programming	Subjects can relate linear programming material to contextual problems.
4	Derivative	The subject understood the rules of the first derivative of algebraic functions for multiplication operations in the form of u and v. However, the subject is still confused about determining whether u.v and v.u.
5	Measure of central tendency	The subject defined mode, median and mean using formulas without the benefit of studying the material in question.

6	Trigonometry	The subject defined trigonometric ratios by writing formulas, without further understanding the meaning of the rules.
7	Matrix	The subject understood the matrix subtraction material and can differentiate between facts, principles, concepts and procedures.
8	Quadratic function	The subject understood the quadratic function material and can differentiate between facts, principles, concepts and procedures. The subject also constructed challenging questions, for example why the value of a cannot be zero in the case of a quadratic function?
9	One variable linear equation	The subject defined one variable linear equation by writing formulas, without further understanding the meaning of the rules.
10	Quadratic equation	Subject has excellent skills in understanding and explaining the general form of quadratic equations.
11	Direct proportion	The subject defined direct proportion by writing formulas, without further understanding the meaning of the rules.

Based on Table 5, the information indicates that the material taught by each subject should not be the same. The material selected is from junior and high school levels, with varying degrees of difficulty. In the final session, the subjects received guidance and suggestions from previous sessions. However, there remains a percentage of subjects, specifically the 36.36%, who made errors in explaining concepts or providing formulas directly without clarifying their meaning (2,5,6,11).

Pedagogical Knowledge (3,36/ Moderate Level)

The subjects' ability to understand learning theories, cognitive development of students, and how to apply these in the classroom is reflected in their choice of appropriate teaching models or strategies for specific content. In the first session, the subjects experienced anxiety and remained focused on technology, which led to a lack of mastery over the steps of the teaching model or strategy to be used in practice. The subjects appeared to interact less with the students, with their gaze and body movements primarily directed at the blackboard. However, in subsequent sessions, the subjects' abilities improved. Additionally, the subjects were guided to design lesson plans (RPP) and determine the teaching strategies or models to be used. Details of the teaching strategies employed can be found in Table 5.

Table 5. Description of TPACK Framework Results for the PK Aspect

Subject number	Learning Models/Methods	Results of Observation P4
1	Problem Based Learning	Subject begins learning by checking students' understanding through questions about concepts.
2	Demonstration	The subject has poor explanation skills. Apart from that, interaction with students is also very limited. The subject only explained the writing on PowerPoint™ without developing new ideas and demonstrating them
3	Connecting, Organizing, reflecting and Extending (CORE)	Subject has good classroom management skills and teach according to the CORE Steps
4	Discovery Learning	Subject uses the discovery learning method via online using Google Classroom
5	STAD	The subject interacted a lot with students and the voice intonation and body gestures used were appropriate for using the STAD type cooperative model.
6	Discussion	Subjects has classroom management skills that need to be improved because discussion methods during the learning process are not yet visible.

7	Lecatoring, Discussion, question & answer method	Voice intonation and subject emphasis on variations skills are appropriate, but interaction with students is still limited
8	Discovery Learning	The subject has already good class mastery and is in accordance with the steps in discovery learning
9	PBL	The subject starts the lesson in a sitting position, so the lesson is less interesting even though the teacher's intonation is appropriate
10	Cooperative Learning: Talking Chips	The subject has already good explanation skills. This can be seen from interactions with students, apperception, gestures and body expressions in using the Talking Chips cooperative model.
11	PBL	The learning steps are appropriate but the intonation is too fast, so that parts of the concept that need emphasis are not visible.

Based on Table 6, Subject 10 used Cooperative Learning: Talking Chips. According to Huda (in Sarifa et al., 2021), talking chips learning model is an example of various cooperative methods that can be adjusted to the understanding of the concept. This learning model is a learning technique designed for discussion.

Pedagogical Content Knowledge (3,31/ Moderate Level)

The suitability between pedagogical skills and the subject's understanding of the material to be taught needs further description. The subjects' ability to emphasize key aspects in teaching mathematics was, at the outset, insufficient. However, improvement was observed in subsequent sessions.

Table 6. Description of TPACK Framework Results for the PCK Aspect

Subject number	Observation indicator	Results of Observation P4
1	Problem Based Learning as a strategy for investigating the definition of sets	Appropriate
2	The demonstration method is not visible in explaining the concept of definite integrals	Inappropriate
3	Connecting, Organizing, Reflecting and Extending (CORE) as a strategy for investigating linear programming problems	Appropriate
4	The discovery learning method is not used to investigate derivatives in multiplication rules	Inappropriate
5	The STAD method as a strategy for investigating the average formula	Appropriate
6	The discussion method is not used in explaining trigonometry	Inappropriate
7	The method used in matrix operations is lecture only, there is no discussion or responsibility.	Inappropriate
8	Discovery Learning as a strategy for investigating graphs of quadratic functions	Appropriate
9	The PBL learning model is not used in the learning process regarding linear equations with one variable	Inappropriate
10	Cooperative Learning Type Talking Chips as a strategy for investigating quadratic equations	Appropriate
11	The PBL model as a strategy for investigating direct proportion	Appropriate

A subject is categorized as appropriate if the learning model or method applied is in accordance with the previously prepared teaching module. Based on Table 6, the percentage of suitability between the instructional model chosen by the subjects and what was implemented is 54.5%. This indicates that more than half of the subjects already possess good pedagogical skills.

Technological Content Knowledge (3,47/Moderate Level)

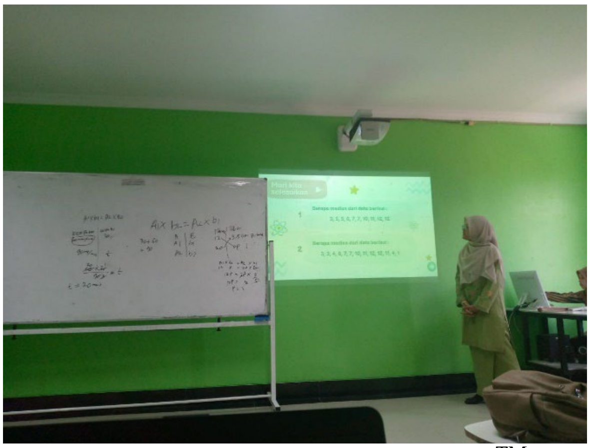
The suitability between the subjects' ability to integrate technology with the material to be taught needs further description. Generally, the subjects use PowerPoint™ to explain the material learning. However, in some cases, the PowerPoint™ slides designed have not facilitated students' understanding. This is because some subjects still merely read what is written on the slides. Additionally, at the beginning of the sessions, some subjects merely downloaded instructional videos from YouTube™ or teaching materials from the internet. However, by the end of the sessions, the subjects had learned to create PowerPoint™ presentations using their own voice and to analyze the material to be taught beforehand.

Table 7. Description of TPACK Framework Results for the TCK Aspect

Subject number	Technology	Observation indicator	Results of Observation P4
1	Quizizz™ and Canva™	Using PowerPoint™ to investigate the system of linear equations in two variables SPLDV	The material on Systems of Linear Equations in Two Variables (SPLDV) is covered in the PowerPoint™ presentation (appropriate).
2	PowerPoint™ and Maple™	Using Maple™ to investigate the solution process using properties of definite integrals.	The PowerPoint™ presentation includes key points of the concepts to be explained (appropriate).
3	GeoGebra™ and Quizizz™	Using GeoGebra™ to investigate tangents to circles	Students don't seem to understand because the subject only reads what is on GeoGebra. Preferably, the focus should be on the blackboard, not the wall, so that it can be crossed out to explain important points that make it easier for students to understand. (inappropriate/improved)
4	PowerPoint™ and Kahoot™ (quiz)	Using PowerPoint to explain multiplication derivative material	In the PowerPoint™ displayed there is no explanation of the process of obtaining the derivative rule formula for multiplication in the form of u.v (inappropriate/improved)
5	Canva™ and Wordwall (quiz)	Using PowerPoint™ to explain measure of central tendency material	The subject does not write on the board as additional explanation or explanation of the concept being taught, only explains from slide (appropriate)
6	Canva™ Presentation Application	Using PowerPoint™ to explain trigonometry material	There is a typing error in the PowerPoint™ used (inappropriate/improved)
7	Canva™ Presentation Application and Bamboozle (quiz)	Using PowerPoint™ to explain matrix material	When writing the symbols on the PowerPoint™ slide, the equal sign is left behind (inappropriate/improved)
8	Microsoft mathematics™	Using Microsoft mathematics™ to solve quadratic function and logarithm problems	Learning to use Microsoft Mathematics (calculator) has begun to be meaningful with theoretical explanations first and then practical exercises using the software (appropriate).
9	GeoGebra™	Using GeoGebra™ to identify elements of flat-sided geometric figures and linear equations in one variable.	Subjects sit in front of a laptop while conducting a learning evaluation. (inappropriate/improved)

10	Website and Quizizz™ (quiz)	Use material on the website to explain quadratic equations	The slide contains images that show the application of the concept of quadratic equations in everyday life, such as the shape of the trajectory of a kicked ball. (appropriate)
11	Quizziz™, Canva™ Presentation Application and YouTube™	Use videos on YouTube for value comparison material and PowerPoint™ to explain the material.	The subject is seen reading out what is in the PowerPoint™ only. (inappropriate/improved)

Based on Table 7, it can be seen that the subjects have used technology in various mathematical materials. However, there were still four mistakes that could be made to improve further, such as typing errors on the slides displayed (6,7), only reading the material on the slides with a sitting gesture (9,11), slides only containing formulas without explanation of the discovery process a concept (4), as well as the lack of additional explanations using a whiteboard when using GeoGebra™ or PowerPoint™ (3). In other words, the percentage of subjects who need to improve the TCK aspect is around 54.5%.



Picture 1. Subject use Powerpoint™

Figure 1 shows an example of one of the subjects explaining the material using a power point slide designed on Canva™. In addition to the use of PowerPoint™, there is also a whiteboard next to it for working on practice questions.

Technological Pedagogical Knowledge (3,27/Moderate Level)

This aspect guides the subjects to integrate technology into lesson planning, teaching execution, and evaluation of mathematics instruction in a manner that aligns with the students' conditions. At the end of the lesson, the subjects conducted an evaluation by administering a quiz using an application and sharing the created link. The quiz administration excited the students, especially for questions discussed individually, compared to discussions held after completing all the questions.

Table 8. Description of TPACK Framework Results for the TPK Aspect

Subject number	Technology	Observation indicator	Results of Observation P4
1	Quizizz™ and Canva™ Presentation Application	Quizizz™ and PowerPoint™ to facilitate PBL	PowerPoint™ helps the subject explain the material because it contains important points, while evaluation uses quizzes
2	Maple™	Maple™ to facilitate demonstration methods	Collaboration between demonstration methods and ICT
3	GeoGebra™ and Quizizz™	GeoGebra™ and Quizizz™ to facilitate CORE	GeoGebra makes students understand concepts better. Collaborating the CORE model with ICT also uses Google Forms.
4	PowerPoint™ and Kahoot™ (quiz)	PowerPoint™ and Kahoot™ (quiz) to facilitate discovery learning	Collaboration between discovery learning methods and ICT
5	Canva™ Presentation Application and wordwall™ (quiz)	Powerpoint™ and Wordwall™ (quizzes) to facilitate STAD	Technology helps subjects appreciate every correct answer so that students are enthusiastic about learning.
6	Canva Presentation Application ™	PowerPoint™ to facilitate discussion methods	Students easily lose focus on what the subject shows
7	Canva Presentation Application™ and Bamboozle™(quiz)	PowerPoint™ and Bamboozle™ (quiz) to facilitate leaturing, discussions and questions &answers method	The subject uses PowerPoint™ to explain the material and Bamboozle quizzes as material for evaluation, the teacher's way of clarifying when there is doubt is using the lecture method but there is no discussion. Apart from that, appreciation for students who answered a lot is recorded in the system well.
8	Microsoft mathematics™	Microsoft mathematics™ to facilitate discovery learning	The subject interacts with the students, if no one answers, they point directly
9	GeoGebra™	GeoGebra™ to facilitate PBL	Collaboration between PBL and ICT models
10	Website and Quizizz™ (quiz)	Website and quizizz (quiz) to facilitate Talking Chips Type Cooperative Learning	Collaboration between the CORE and ICT models
11	Quiz (Quizziz™), Canva Presentation Application™, YouTube™	Quiz (Quizziz™), PowerPoint™, Youtube™ videos to facilitate PBL	Collaboration between PBL and ICT models is still lacking

Based on Table 8, it can be seen that in general subjects carry out evaluations by giving quizzes at the end of the lesson using the Quizizz™, Kahoot™, Wordwall™ and Bamboozle™.

Technological Pedagogical Content Knowledge (3,33/Moderate Level)

The subject's abilities in the TPCK aspect can be seen in Table 9 below.

Table 9. Description of TPACK Framework Results for the TPCK Aspect

Subject number	Technology	Learning material	Learning models/ methods	Observation indicator	Results of Observation P4
1	Quizizz™ and Canva™	Set	Problem Based Learning	Integration of Quizizz™ and PowerPoint™	The subject begins the lesson by asking challenging questions such

	Presentation Application			(Canva™) with PBL strategies to teach set content	as whether two-year-old students are in the empty group?
2	PowerPoint™ and Maple™	Integral	Demonstration	PowerPoint™ and maple integration with to teach Integral content	The subject is more dominant in ICT (maple applications), collaboration in use still feels very limited,
3	GeoGebra™ and Quizizz™	Linear Program	Connecting, Organizing, reflecting and Extending (CORE)	GeoGebra™ and Quizizz™ integration with to teach linear programming content	The use of PowerPoint™ in explaining graphics is very effective. However, the subject should also explain the graph manually. Collaboration with pedagogy is also starting to get better
4	PowerPoint™ and Kahoot™ (quiz)	Derivative	Discovery Learning	PowerPoint™ and Kahoot™ integration with to teach derivative content	Evaluation of learning using Kahoot™
5	Canva™ Presentation Application and wordwall™ (quiz)	Central tendency	STAD	PowerPoint™ and wordwall™ integration with to teach central tendency content	Subjects did not utilize existing facilities because explaining the material was done orally without using a whiteboard. It should be able to be written on PowerPoint™
6	Canva™ Presentation Application	Trigonometry	Discussion	PowerPoint™ integration with to teach content	Collaboration between the three aspects of TPACK is still lacking
7	Canva™ Presentation Application and Bamboozle™ (quiz)	Matrix	Leatoring, Discussion, question & answer method	Integration with to teach trigonometry content	Collaboration between the three aspects of TPACK is still lacking. However, when the quiz was given, the students became enthusiastic again.
8	Microsoft mathematics™	Quadratic function	Discovery Learning	Integration of Microsoft Math with to teach quadratic function content	The subject initially had problems sharing the screen, but this was quickly overcome. Use of Quiz whizzer™ at the end of the lesson
9	GeoGebra™	One variable linear equation	PBL	GeoGebra™ integration with to teach content Linear equations in one variable	There is a content match with technology, but pedagogical content is still low, because the subject does not seem to dominate the class
10	Website and quizizz™ (quiz)	Quadratic equation	Cooperative Learning: Talking Chips	Integration of website and Quizizz™ with to teach quadratic equation content	Collaboration between pedagogical abilities, mastery of teaching materials and use of technology begins to balance, evaluation at the end of learning by giving Quizizz™.
11	Quiz (quizziz™), Canva™ Presentation	Direct proportion	Problem Based Learning	Integration of Quizizz and PowerPoint™ with to teach value comparison content	The subject does not master the concept, so every time they look at the PowerPoint

	Application, Youtube™ video		slides and the whiteboard, the students are ignored.

Discussion

The average questionnaire score for TK aspect was 3.47 (medium category). The type of technology used is mathematics software, namely Maple™, GeoGebra™, PowerPoint™, Canva™, Microsoft Mathematics™, YouTube™ Video and Website. Canva™ is an application that can create attractive visual learning media designs (Kharissidqi & Firmansyah, 2022). Four types of quiz applications are: Quizizz™, Kahoot™, Wordwall™ and Bamboozle™. Each of the four quiz applications has its own advantages and disadvantages. The ability of prospective teacher students to select and integrate technology in learning influences the impact of using that technology. This is in line with Gentile & Pisanu, (2013) which states that to evaluate the impact of technologies should be considered the following levels of analysis: a) technologies (devices and software); b) school (learning environments, principal leadership styles); c) teacher (digital skills, use versus integration of technologies); d) student (learning outcomes, educational outcomes.

Furthermore, the average questionnaire score for the CK aspect was 3.44 (medium category). The results of this study are in line with research conducted by Purwoko (2017) which states that the CK abilities of prospective mathematics teacher students are predominantly at good and strong level. As many as 36.3% of students have not mastered the facts, concepts, procedures of a topic in the mathematics learning process. There are several concepts that student teachers have not yet mastered. This will have an impact on their explanation skills in front of the class. Teachers with strong conceptual understanding tend to be more effective in explaining concepts and implementing teaching strategies that support student understanding.

The average questionnaire score for the PK aspect is 3.36 (medium category). The learning models chosen by student teachers are the Problem Based Learning Model, Demonstration Method, Talking Chips STAD Cooperative Learning Model, CORE (Connecting, Organizing, Reflecting and Extending) Learning Model, Discussion Method, Lecture Method and Question and Answer Method. The average questionnaire score for the PCK aspect is 3.31 (medium category). The percentage of suitability of the learning model chosen by the subject to that implemented was 54.5% or as many as six students.

The average questionnaire score for the TCK aspect is 3.47 (medium category). The percentage of subjects who need to improve the TCK aspect is around 54.5%. This shows that the technology used is still not integrated into the learning process. Subjects copy full material from the internet without understanding. This is in line with research conducted by Satriawati et al., (2022) which states that the videos used by students are videos that are already available on the internet, only a few students are able to make PowerPoint™. The available evidence on the relationship between teachers' pedagogical beliefs and their uses of technology (Tondeur et al., 2017).

The average questionnaire score for the TPK aspect was 3.27 (medium category). In the learning process, prospective teacher students carry out evaluations by giving quizzes using an application dominated by Quizizz™ at the end of the lesson. In this aspect, there is a tendency for differences between the results of direct observation and the results of the questionnaire filled out by students. For example, the item "I can utilize available technologies as a learning aid" indicates a high rating (3.63); however, observations indicate that students' abilities are still lacking, indicating that students have much to learn, especially in the use of technology in the learning process to enhance the learning environment in mathematics.

Furthermore, the average questionnaire score for the TPCK aspect was 3.33 (medium category). In several aspects, differences can be seen between the results of questionnaires filled out by pre-service teacher students and the results of observations. Where the observation results tend to be lower than the questionnaire results. The integration of technology in mathematics learning by several subjects is still not optimal.

The TPACK abilities of pre-service teachers were low at the first meeting and increased to moderate by the last meeting. This contrasts with the questionnaire results, which indicated that students' TPACK abilities were moderate at the beginning. The findings of this study suggest efforts should be made to assess the alignment of students' responses and the challenges faced in the field by developing more flexible instruments. Based on the observations, generally, technology is used as a learning tool by the pre-service teachers, but not yet at the stage of developing mathematical concepts. One of the functions of technology in mathematics learning is developing conceptual understanding (Putrawangsa & Hasanah, 2018). Furthermore, educators could diversify technology integration in mathematics (Hidayat & Firmanti, 2024).

Conclusion

The distribution of TPACK abilities of pre-services teacher is overall in the medium category with an average questionnaire score of 3.38. The highest score is 3.47 for both aspects of Technological Knowledge and Technological Content Knowledge. The lowest score is 3.27 for aspect of Technological Pedagogical Knowledge. On the other hand, there are differences in the results of questionnaires filled out by students directly and the results of observations. The ability scores of student's TPACK from observations tend to be lower than the questionnaire results. The results of this research show how important observations are in assessing the suitability of students' answers and the obstacles that occur in the field.

The limitation of this study is the small sample size so that the findings cannot be generalized to other groups. It is hoped that further research will use a larger sample. In addition, the evidence used to evaluate pedagogical content knowledge (PCK) is too limited. It is difficult to observe student's ability to make a relationship between learning theories and the mathematics content that supports 4C skills.

References

Amrina, Z., Anwar, V. N., Alvino, J., & Sari, S. G. (2022). Analisis Technological Pedagogical Content Knowledge Terhadap Kemampuan Menyusun Perangkat Pembelajaran Matematika Daring Calon Guru SD. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *6*(1), 1069–1079. https://doi.org/10.31004/cendekia.v6i1.1313

Blegur, J., Ma'mun, A., Mahendra, A., Mahardika, I. M. S., & Tlonaen, Z. A. (2023). Bibliometric analysis of micro-teaching model research trends in 2013-2023. *Journal of Innovation in Educational and Cultural Research*, *4*(3), 523–533. https://doi.org/10.46843/jiecr.v4i3.782

Faradilla, H., & Putra, A. (2024). Technological, Pedagogical, and Content Knowledge (TPACK) Mahasiswa Tahun Ketiga Calon Guru Matematika. *Jurnal Silogisme : Kajian Ilmu Matematika Dan Pembelajarannya*, *9*(1), 27–41.

Farida, N., & Kusumawati, F. P. (2024). Analisis Kemampuan TPACK Calon Guru melalui Microteaching Lesson Study. *Edukatif : Jurnal Ilmu Pendidikan*, *6*(5), 5767–5773. https://doi.org/10.31004/edukatif.v6i5.7511

Gentile, M., & Pisanu, F. (2013). Integrating technology and teaching with Learning Solutions. *Learning & Teaching with Media & Technology Conference Proceedings*, *June 2013*, 272–286.

Herizal, H., Nuraina, N., Rohantizani, R., & Marhami, M. (2022). Profil TPACK Mahasiswa Calon Guru Matematika dalam Menyongsong Pembelajaran Abad 21. *JISIP (Jurnal Ilmu Sosial Dan Pendidikan)*, *6*(1), 1847–1857. https://doi.org/10.58258/jisip.v6i1.2665

Hidayat, A., & Firmanti, P. (2024). Navigating the tech frontier: a systematic review of technology integration in mathematics education. *Cogent Education*, *11*(1). https://doi.org/10.1080/2331186X.2024.2373559

Jenita, Harefa, A. T., Pebriani, E., Hanafiah, Rukiyanto, B. A., & Sabur, F. (2023). Pemanfaatan Teknologi Dalam Menunjang Pembelajaran: Pelatihan Interaktif Dalam Meningkatkan Kualitas Pendidikan. *Communnity Development Journal*, *4*(6), 13121–13129.

Kharissidqi, M. T., & Firmansyah, V. W. (2022). Aplikasi Canva Sebagai Media Pembelajaran Yang Efektif. *Indonesian Journal Of Education and Humanity*, *2*(4), 108–113.

Koehler, M. J., Mishra, P., Akcaoglu, M., & Rosenberg, J. M. (2013). The Technological Pedagogical Content Knowledge Framework for Teachers and Teacher Educators. *ICT Integrated Teacher Mducation Models*, *December*, 1–8.

Li, M., Vale, C., Tan, H., & Blannin, J. (2024). A systematic review of TPACK research in primary mathematics education. In *Mathematics Education Research Journal* (Issue 0123456789). Springer Netherlands. https://doi.org/10.1007/s13394-024-00491-3

Meisuri, M., Nuswantoro, P., Mardikawati, B., & Judijanto, L. (2023). Technology Revolution in Learning: Building the Future of Education. *Journal of Social Science Utilizing Technology*, *1*(4), 214–226. https://doi.org/10.55849/jssut.v1i4.660

Mukuka, A., & Alex, J. K. (2024). Review of research on microteaching in mathematics teacher education: Promises and challenges. *Eurasia Journal of Mathematics, Science and Technology Education*, *20*(1), 1–15. https://doi.org/10.29333/ejmste/13941

Murtiyasa, B., & Atikah, M. D. (2021). Kemampuan Tpack Mahasiswa Calon Guru Matematika Pada Mata Kuliah Praktikum Pembuatan Alat Peraga Matematika. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *10*(4), 2577. https://doi.org/10.24127/ajpm.v10i4.4351

Nuangchalerm, P. (2020). TPACK in ASEAN perspectives: Case study on thai pre-service teacher. *International Journal of Evaluation and Research in Education*, *9*(4), 993–999. https://doi.org/10.11591/ijere.v9i4.20700

Oktaviana, E., & Yudha, C. B. (2022). Tecnological Pedagogical Content Knowledge (TPACK) Dalam Pembelajaran Abad Ke-21. *Social, Humanities, and Educational Studies (SHEs): Conference Series*, *5*(2), 57. https://doi.org/10.20961/shes.v5i2.58305

Omoso, E., & Odindo, F. (2020). TPACK in Teacher Education: Using Pre-Service Teachers' Self-Reported TPACK To Improve Pedagogic Practice. *International Journal of Education and Research*, *8*(5), 125–138.

Purwoko, R. Y. (2017). Analisis Kemampuan Content Knowledge Mahasiswa Calon Guru Matematika pada Praktek Pembelajaran Mikro. Universitas Negeri Yogyakarta. *Jurnal Pendidikan Surya Edukasi (JPSE)*, *3*, 55–65.

Putrawangsa, S., & Hasanah, U. (2018). Integrasi Teknologi Digital Dalam Pembelajaran Di Era Industri 4.0. *Jurnal Tatsqif*, *16*(1), 42–54. https://doi.org/10.20414/jtq.v16i1.203

Rohmitawati, R. (2018). The Implementation of TPACK (Technology, Pedagogy, and Content Knowledge) Framework on Indonesian Online Mathematics Teachers Training. *Southeast Asian Mathematics Education Journal*, *8*(1), 61–68. https://doi.org/10.46517/seamej.v8i1.64

Saliman, Supardi, & Rosardi, R. G. (2017). Pemahaman Mahasiswa Peserta Pengajaran Mikro terhadap Kurikulum 2013 di Jurusan Pendidikan IPS, FIS, UNY. *JIPSINDO*, *4*(1), 58–77.

Sarifa, Z., Wardani, S., Sulistyaningsih, T., & Purniawati, H. (2021). Penerapan Model Talking Chips Untuk Mengukur Hasil Belajar Dan Kecerdasan Interpersonal. *Jurnal Inovasi*

Pendidikan Kimia, *15*(2), 2885–2896. https://doi.org/10.15294/jipk.v15i2.17464

Satriawati, G., Mas'ud, A., Dwirahayu, G., Dahlan, J. A., & Cahya, E. (2022). Analisis Kemampuan Technological Pedagogical Content Knowledge (TPACK) Mahasiswa Program Studi Pendidikan Matematika Pada Mata Kuliah Microteaching Di Masa Pandemi Covid 19. *FIBONACCI: Jurnal Pendidikan Matematika Dan Matematika*, *8*(1), 73. https://doi.org/10.24853/fbc.8.1.73-84

Schmidt, D. A., Thompson, A. D., Koehler, M. J., & Shin, T. S. (2014). *CIE 2014 - 44th International Conference on Computers and Industrial Engineering and IMSS 2014 - 9th International Symposium on Intelligent Manufacturing and Service Systems, Joint International Symposium on "The Social Impacts of Developments in Informat*, *42*(2), 2531p.

Sholeh, muh ibnu, & Efendi, N. (2023). Integrasi Teknologi Dalam Manajemen Pendidikan Islam: Meningkatkan Kinerja Guru di Era Digital. *Jurnal Tinta*, *5*(2), 104–126.

Siregar, R. K. (2021). Belajar Micro Teaching melalui Pembelajaran Daring. *Ideas: Jurnal Pendidikan, Sosial, Dan Budaya*, *7*(3), 11. https://doi.org/10.32884/ideas.v7i3.395

Sugiyono. (2014). *Metode penelitian pendidikan: Pendekatan kuantitatif, kualitatif, dan R&D*. Bandung: Alfabeta

Tamur, M., Ndiung, S., Weinhandl, R., Wijaya, T. T., Jehadus, E., & Sennen, E. (2023). Meta-Analysis of Computer-Based Mathematics Learning in the Last Decade Scopus Database: Trends and Implications. *Infinity Journal*, *12*(1), 101–116. https://doi.org/10.22460/infinity.v12i1.p101-116

Tondeur, J., van Braak, J., Ertmer, P. A., & Ottenbreit-Leftwich, A. (2017). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: a systematic review of qualitative evidence. *Educational Technology Research and Development*, *65*(3), 555–575. https://doi.org/10.1007/s11423-016-9481-2