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Measuring Preservice Mathematics Teachers' Technological Pedagogical and Content Knowlede in the Post-Pandemic Era

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Abstract

Technological Pedagogical and Content Knowledge (TPACK) represents the essential knowledge that teachers must master. TPACK consists of seven dimensions: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK) and the integration of all these in Technological Pedagogical and Content Knowledge (TPACK). During the COVID-19 pandemic, lectures were shifted online, significantly impacting the TPACK development of pre-service math teachers. This research aims to contribute to the existing literature by examining how online lectures during a pandemic influence the TPACK of pre-service teachers. The study involves assessing the TPACK of 129 pre-service teachers who participated in both online lectures and offline Field Introduction of School activities. A sample of 39 students was selected using stratified random sampling. Data collection instruments included a self-assessment questionnaire, three open-ended questions answered by students, and performance assessments completed by tutors. Despite the challenges posed by online lectures during the pandemic, students demonstrated a good overall proficiency in TPACK, with Technological Knowledge (TK) exhibiting the highest achievement. However, other dimensions of TPACK showed weaker performance, likely due to obstacles encountered during online learning, such as difficulties in delivering material and engaging in online microteaching practices.

Keywords: Online Learning, Post-Pandemic, Preservice Mathematics Teachers, TPACK, Questionnaire

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INTRODUCTION

The COVID-19 pandemic has changed many things in human life, such as the learning system. Along with social restrictions imposed to limit coronavirus transmission, schools must implement online distance learning (Irfan et al., 2020; Syafi'i & Anam, 2022). Schools and universities in Indonesia apply regulations regarding online learning as a response to minimizing COVID-19 transmission in the university. This regulation certainly faces various obstacles from lecturers and students (Irfan et al., 2020). Changing from face-to-face to distance learning in a short time and massively by involving the Internet is not easy for those who do not have adequate educational technology infrastructure (Juanda et al., 2021).

Implementing technology-assisted learning is an important topic, as today's students use technology in various aspects of their lives, including learning (Saralar et al., 2018). Various innovations have been developed to integrate technology into learning. Many researchers state that technology is an important component of learning, but there are still educators who do not have sufficient skills to use technology in class (Wang et al., 2018). Professional teachers should have the skills to design and implement conductive learning (Mutlu et al., 2019).

The rapid improvement of science has changed the demands for teacher competence, including

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the competence to integrate Information and Communication Technology (ICT) in learning (Chai et al., 2020). Technology brings new challenges for teachers in developing technical knowledge and integrating it with learning materials that can assist teachers in conveying concepts, principles, and procedures (Juanda et al., 2021). ICT is important in education to create analogies, illustrations, examples, and demonstrations that can be understood by students easily (Bueno et al., 2021). Pre-service teachers should teach with technological sophistication, especially in online learning (Lyublinskaya & Du, 2022). As technology is always improving and updating, teachers should upgrade their knowledge of technology, operate digital tools, and develop and adapt to new technologies (Bueno et al., 2021). Therefore, implementing online learning requires involvement in mastering technology, which is a challenge for teachers (Juanda et al., 2021).

The teacher plays a major role in carrying the meaning and spirit of technology. They also play a crucial role in facilitating functional, effective, and efficient dissemination of new information and fostering connections between students and information technology. Therefore, teachers' use of technology becomes a major factor in integrating technology into education (Uslu & Güner, 2022). As one of the determining factors in realizing quality education, teachers also play a role in fostering students as human beings in the context of national education (Perdani & Andayani, 2022; Turmuzi & Kurniawan, 2021). Becoming a teacher requires specific knowledge and skills, so they should be able to design an effective learning environment (Mutlu et al., 2019). However, pre-service mathematics teachers who have taken formal education are not capable enough to integrate technology into the learning process (Wang et al., 2018; Marbán & Mulenga, 2019). The quality and quantity of pre-service teacher experience influence student learning outcomes and students' understanding of technology (Saralar et al., 2018; Uslu & Güner, 2022).

University education provides students with knowledge and experience and focuses on developing technological knowledge and skills. This objective is outlined in the education curriculum for pre-service teachers (Uslu & Güner, 2022). Therefore, students should update their technological developments and practice to learn in real conditions (Saralar et al., 2018).

The teaching activity is a complex activity that involves various types of knowledge. Teaching activities are based on knowledge about the subject matter, how to teach a subject, and the use of various technologies; all have an intersection to support one another (Koehler et al., 2013). TPACK is the knowledge that relies on the interaction of technology, pedagogy, and learning content (Lyublinskaya & Du, 2022). The TPACK framework is a conceptual framework for researchers and educators to analyze basic knowledge teachers need (technological, pedagogical, and content and their interrelated interactions). It developed when integrating ICT into learning (Mishra, 2019; Chai et al., 2020; Zhang & Tang, 2021; Uslu & Güner, 2022). TPACK describes basic knowledge for teachers to use technology effectively in math learning (Mutlu et al., 2019). A lack of teacher TPACK can result in ineffective learning (Marbán & Mulenga, 2019; Juanda et al., 2021). Mishra and Koehler define seven dimensions of TPACK (Zhang & Tang, 2021; Uslu & Güner, 2022) as shown in Table 1.

Table 1. Dimensions of TPACK

Dimensions	Description
TK	Knowledge of technology features, capacities, and uses
PK	Knowledge of learning and teaching, including methods, ways, and processes
CK	Knowledge of the subject matter
TPK	Knowledge of the existence of technology that can support the learning process
TCK	Knowledge of how to present subject matter using technology
PCK	Knowledge of how to teach specific subject matter
TPACK	Knowledge to teach and deliver subject matter with the support of technology

Much research has been done on the TPACK of pre-service teachers and the development of the instruments (Tan et al., 2019; Rahmadi et al., 2020; Irwanto et al., 2022), considering that this ability will determine how learning that they will carry out later (Saralar et al., 2018). Previous research has measured the TPACK of pre-service teachers in offline learning on various subjects. However, as far as is known, no studies have investigated how online lectures during a pandemic can affect the TPACK of pre-service teachers. This research will measure the TPACK of the pre-service teacher who has taken online lectures for five semesters. This research is important to carry out considering that in the future, it is very likely that online learning will continue, so it is necessary to know the TPACK of students who have participated in online learning.

METHODS

This research is a descriptive qualitative study conducted on 129 students. The subjects were chosen using stratified random sampling by grouping them based on the class during online lectures, as shown in Table 2.

Table 2. Population and sample

Class	Population	Sample (30%)
1	29	9
2	36	11
3	37	11
4	27	8
Total	129	39

Data was obtained using a questionnaire filled out by pre-service teachers as a self-assessment and a questionnaire filled out by tutors during teaching practice as a performance assessment of student practice abilities. The questionnaire consists of 10 self-assessments and 4 statement items with 5 Likert scales (strongly disagree, disagree, neutral, agree, and strongly agree) for the seven dimensions of

TPACK and three open-ended questions related to mastery of technology, pedagogy, and math content after the online lecture.

RESULTS AND DISCUSSION

Data results of this research are described as questionnaire responses for TK (Table 3), PK (Table 4), CK (Table 5), TPK (Table 6), TCK (Table 7), PCK (Table 8) and TPACK (Table 9). Each statement consists of 5 Likert scales: Strongly Disagree (SD), Disagree (D), Neutral (N), Agree (A), and Strongly Agree (SA). The results of data analysis in Table 3 and open-ended questions show that students can update various technological improvements easily. They enjoy learning about new technological developments important for them as pre-service teachers. They also could use devices in their daily activities, able to overcome technical problems on their devices, master word and number processing software, presentation programs, and image editing software, able to use communication facilities online, able to use updated social media, able to use online meeting media, able to use media projectors, printers, scanners, and digital cameras properly.

Students argue that implementing online learning increases their mastery of technology. This is because, during the pandemic, communication is more often carried out online. Therefore, students are increasingly proficient in using communication media such as WhatsApp, Telegram, and e-mail. When learning online, lecturers and students must be skilled in using online communication devices. Online communication media include Zoom, Google Meet, Jitsi, and Google Duo.

Table 3. Questionnaire responses for TK

Methods	No	Statement	Frequency				
			SD	D	N	A	SA
Self-assessment	1	I can use various technological developments easily	3	0	4	22	10
	2	I am used to using gadgets in my daily activities	2	0	3	10	24
	3	I can overcome technical problems on my gadgets	2	3	5	19	10
	4	I master word, number, presentation, and image processing programs	0	2	7	25	5
	5	I can use communication tech via online media	2	0	0	12	25
	6	I can use the updated social media	2	0	3	13	21
	7	I can use online meeting media	1	1	3	15	19
	8	I can use projectors, printers, scanners, and digital cameras	1	3	8	18	9
	9	During online lectures, my mastery of communication technology became better	1	1	9	15	13
	10	I enjoy learning about new technological developments that are important to me as a future teacher	1	2	3	17	16

Methods	No	Statement	Frequency				
			SD	D	N	A	SA
Performance assessment	1	Student master word, number, presentation, and image processing programs	0	0	2	22	15
	2	Students can use projectors, printers, scanners, and digital cameras	0	0	1	18	20
	3	Students can use online meeting media	0	0	5	19	15
	4	Students can use communication facilities via online media	0	0	0	10	29

The results of data analysis in Table 4 and open-ended questions show that students can design and manage mathematics learning in class, adapt to student's learning styles, evaluate students' content understanding, motivate students so they are enthusiastic about learning mathematics, use visual devices to convey subject matter, and apply various models, approaches, strategies, methods, and techniques of learning mathematics properly. However, students also conquer difficulties conveying subject matter even though they understand it, preparing lesson plans and assessment instruments, and understanding students' character.

Regarding lectures previously held online, students felt less confident about teaching in front of the class. This is because, during the pandemic, lectures were held online, so they were not communicating and delivering subject matter directly to other people. They feel that communicating offline is a challenge, so they must learn to adapt again. In addition, the practice of microteaching, which is carried out online, also affects student PK. They practice communicating and teaching subject matter online in microteaching but must carry out offline learning at school. This is certainly different and becomes an obstacle for them.

Table 4. Questionnaire responses for PK

Methods	No	Statement	Frequency				
			SD	D	N	A	SA
Self-assessment	1	I can design math learning in class	2	0	3	23	11
	2	In learning math, I can manage the class well	1	2	10	17	9
	3	I often have difficulty conveying mathematics material to students even though I understand it	5	6	11	12	5
	4	I can apply various models, approaches, strategies, methods, and techniques for learning math	1	5	14	15	4
	5	I feel inadequate if I have to use visual aids to convey math content	8	13	13	5	0
	6	I have difficulty understanding the characters of the students in class	4	15	11	9	0
	7	Preparing lesson plans and assessment instruments is a tough thing for me	1	6	21	5	6
	8	I can adapt to students' learning styles	0	4	9	19	7
	9	I can evaluate students' understanding of the content	0	3	12	19	5

Methods	No	Statement	Frequency				
			SD	D	N	A	SA
Performance assessment	10	I always provide motivation that makes students enthusiastic about learning math	1	1	6	22	9
	1	Students can manage the class well	0	0	1	28	10
	2	Students can apply various models, approaches, strategies, methods, and techniques for learning math	0	0	4	29	6
	3	Students can evaluate students' understanding of content	0	0	3	30	6
	4	Students are skilled at using visual aids in presenting math contents	0	0	6	24	9

The results of data analysis in Table 5 and open-ended questions show that students can master school math, make contextual math problems, solve various kinds of school math problems, understand facts, concepts, principles, and procedures in school math, and understand the interrelationships of math content with other subject matter and students' daily life. However, students face difficulties solving HOTS problems, designing math problems from the lowest to the highest levels, and proving theorems.

During online lectures during the pandemic, students found it quite difficult to understand math content. This is because the delivery of math content online is not optimal. Some students face problems with the internet network, so they don't fully follow the explanation of the math content. Online lectures also have a lot of distractions, so they are less focused. As a result, there is a lack of mastery of math content.

Table 5. Questionnaire responses for CK

Methods	No	Statement	Frequency				
			SD	D	N	A	SA
Self-assessment	1	I master the math contents taught at school well	0	3	6	24	6
	2	I often have difficulty solving HOTS-type math problems	1	12	17	7	2
	3	I can design math problems from the lowest level to the highest	0	1	24	11	3
	4	I can create contextual math problems	1	1	15	16	6
	5	I can solve various kinds of school math problems	1	1	14	18	5
	6	I understand the facts, concepts, principles, and procedures in school math	1	3	12	21	2
	7	I have difficulty understanding the mathematics material taught during online lectures	2	5	17	10	5
	8	Proving a theorem or statement in math is difficult for me	2	2	13	18	4
	9	I can understand the relationship between math contents and material in other subjects	0	4	12	17	6
	10	I can relate math content to student' daily lives	1	0	9	21	8

Methods	No	Statement	Frequency				
			SD	D	N	A	SA
Performance assessment	1	Students master the math contents taught at school well	0	0	2	22	15
	2	Students can solve various kinds of school math problems	0	0	5	23	11
	3	Students can design math questions as evaluation instrument	0	0	6	25	8
	4	Students can provide examples of the relationship between math contents in everyday life	0	0	7	24	8

The results of data analysis in Table 6 and open-ended questions show that students can use technology-based learning, choose appropriate teaching devices or media, present mathematical material, choose the appropriate technology for learning approaches and strategies, adjust the use of technology for different learning materials and activities, design math tasks using learning devices, media, or software, use audiovisual media in learning, and design learning devices using computer app. However, students face difficulties discussing and presenting math topics online, preparing learning content using technology, and designing interesting learning videos for students.

Students argue that mathematics is often difficult and involves various abstract symbols. Discussing or delivering math topics online is a challenge because online media such as WhatsApp or email do not have features for typing math symbols. Preparing learning materials and media such as learning videos is also a challenge for pre-service teachers because using video processing software requires skills, time, and creativity.

Table 6. Questionnaire responses for TPK

Methods	No	Statement	Frequency				
			SD	D	N	A	SA
Self-assessment	1	I can use technology-based learning media in learning	2	1	9	21	6
	2	I can choose props and media that suit the math contents for learning	1	2	11	19	6
	3	I am used to discussing math content with students via online media	3	11	19	5	1
	4	Presenting math content in class using audiovisual media is not difficult for me	0	3	11	19	6
	5	Delivering math content online is not difficult for me	2	6	20	8	3
	6	I choose technology that suits my learning approach and strategy	2	3	11	18	5
	7	I adapt the use of the technology learned to different learning activities and contents	0	3	11	20	5
	8	I have difficulty preparing content using technology, both teaching aids/media and software	3	12	20	2	2
	9	I can create interesting math learning videos for students	1	3	19	12	4

Methods	No	Statement	Frequency				
			SD	D	N	A	SA
Performance assessment	10	I can design mathematics assignments for students by involving technological developments	2	1	14	17	5
	1	Students can use technology-based learning media in learning	0	0	1	27	11
	2	Students are skilled at using audiovisual media in learning math in class	0	0	5	27	7
	3	Students can adapt the use of the technology studied for different learning activities and materials	0	0	3	30	6
	4	Students are skilled at designing learning devices with the help of various computer applications	0	0	7	24	8

The results of data analysis in Table 7 and open-ended questions show that students often use online media as a reference to improve math understanding, know various software related to mathematics, choose the right technology according to math topics, know which technology can support math learning, and use communication technology to discuss math topics. However, students are not very good at using computer apps as tools to solve math problems, understand the role of mathematics in technological development, and describe math topics with technology. They still face difficulty solving math problems using computer apps.

Table 7. Questionnaire responses for TCK

Methods	No	Statement	Frequency				
			SD	D	N	A	SA
Self-assessment	1	I am familiar with various software related to math contents	1	3	16	14	5
	2	To increase my understanding of math content, I often use online media as a reference	2	1	4	17	15
	3	I am used to using computer applications as tools to solve math problems	3	4	15	13	4
	4	During online lectures, I am used to using communication technology to discuss and ask experts if there are difficulties in understanding math contents	2	3	12	15	7
	5	I understand the role of mathematics in technological development	2	2	16	15	4
	6	I know various software related to math contents	1	1	16	14	7
	7	I can explain math contents by utilizing technology, including media, teaching aids, and software	1	3	17	14	4
	8	I can choose the right technology (visual aids/media/software) with math content	0	4	15	16	4
	9	I know various technologies that I can use to learn math contents	0	1	18	18	2
	10	I often have difficulty solving math problems using computer applications	2	7	19	8	3

Methods	No	Statement	Frequency				
			SD	D	N	A	SA
Performance assessment	1	Students demonstrate skills in using computer applications related to math contents	0	1	8	24	6
	2	Students often use online media as references in explaining math contents	1	3	5	26	4
	3	Students are skilled at using computer applications as a tool in solving math problems	0	2	8	23	6
	4	Students can use communication technology to discuss math contents	0	0	4	27	8

The results of data analysis in Table 8 and open-ended questions show that students can choose appropriate learning methods to overcome their difficulties in understanding the concept, arrange the stages of the math topics correctly to support the elaboration of the concept being taught, choose the math topics in learning according to the level of student's cognitive development, deliver complex math topics so that it is easy to understand, present the correlation between math topics, and design HOTS problems for students. However, they face difficulties in designing learning according to the level of students' understanding, developing curriculum and syllabus, compiling questions to evaluate student understanding, compiling questions to measure all students' cognitive levels, and conveying complex content.

Table 8. Questionnaire responses for PCK

Methods	No	Statement	Frequency				
			SD	D	N	A	SA
Self-assessment	1	I can design lessons according to student's level of understanding and the contents they have studied	0	3	18	16	2
	2	I can choose appropriate learning methods to overcome students' difficulties in understanding the math content	0	3	11	19	6
	3	I can arrange the stages of math contents correctly to support the explanation of the material being taught	1	1	11	19	7
	4	I can choose the math contents presented according to the student's level of development	1	2	9	23	4
	5	I can convey difficult math content so that it is easy for students to understand	1	2	15	15	6
	6	I can develop a curriculum and syllabus according to the sequence of math content	0	3	16	18	2
	7	I often have difficulty in preparing questions to evaluate students' understanding in learning math	4	9	19	7	0
	8	I am used to conveying the relationship between math content in learning	0	1	14	19	5
	9	I can create math problems to measure math LOTs, MOTs, and HOTs	1	1	21	10	6

Methods	No	Statement	Frequency				
			SD	D	N	A	SA
Performance assessment	10	I often find it difficult to convey math content that is considered complicated to students	2	7	18	8	4
	1	Students can convey math content that is considered difficult to make it easy for students	0	0	11	23	5
	2	Students can develop learning tools according to the sequence of math contents	0	0	5	27	7
	3	Students can design HOTS-type math problems	0	0	15	23	1
	4	Students can explain the relationship between math content in the learning process	0	0	4	30	5

The results of data analysis in Table 9 and open-ended questions show that students can choose the right media, teaching devices, and apps to solve math problems, assess students' work in solving math problems, choose appropriate learning strategies and technologies, integrate math knowledge, pedagogical, and technology for effective learning, use appropriate technology to deliver math topics, choose appropriate technology to improve student's math understanding using learning strategies, integrate appropriate technology and learning strategies in math learning, integrate technology and learning methods to deliver math topics, evaluate students understanding with technology, choose appropriate learning strategies and technologies in learning activities, and carry out good learning by combining the use of appropriate technology and learning strategies in math subjects. However, students still face difficulty integrating technology with the methods to deliver math topics, evaluating math learning combined with technology, and correlating technology to math topics.

Table 9. Questionnaire responses for TPACK

Methods	No	Statement	Frequency				
			SD	D	N	A	SA
Self-assessment	1	I have difficulty integrating technology with the methods used to teach math content	3	6	19	9	2
	2	I can evaluate math learning combined with technology based on indicators	1	3	20	14	1
	3	I can connect technology (visual aids/software) to teaching various math content	2	1	25	9	2
	4	I can choose the right media, props, and applications to solve math problems	1	2	11	21	4
	5	I can assess students' work in solving math problems	0	2	6	21	10
	6	I choose learning strategies and technology that are appropriate to the math contents that will be presented in learning activities	0	3	10	21	5
	7	I combine math knowledge, pedagogical knowledge, and technological knowledge to create effective learning for students	1	2	15	17	4

Methods	No	Statement	Frequency				
			SD	D	N	A	SA
	8	I use appropriate technology and appropriate learning strategies to deliver math content well in the classroom	0	0	15	20	4
	9	I can choose the right technology to improve students' understanding of the math contents that I teach using certain learning strategies in the classroom	1	1	16	17	4
	10	I can carry out good learning by combining the use of appropriate technology and appropriate learning strategies in math subjects	1	2	15	16	5
Performance assessment	1	Students can combine technology with the methods used to teach math content	0	0	11	22	6
	2	Students can evaluate math learning combined with technology based on indicators	0	0	12	20	7
	3	Students can choose learning strategies and technology that are appropriate to the math contents that will be presented in learning activities	0	0	8	28	3
	4	Students can carry out good learning by combining the use of appropriate technology and appropriate learning strategies in math subjects	0	0	9	25	5

In general, student achievement in the TK dimension is the best. This was influenced by learning previously carried out online during the pandemic. Unfortunately, online learning also affects students' lack of mastery of pedagogical knowledge and mathematical content. In the end, another dimension, the interaction of knowledge, pedagogical, and mathematical content, is also affected.

The results of this study indicate that online lectures during the pandemic increase the TK of the pre-service teacher. As mentioned in previous research, the advantages of online learning are that it is more flexible and has a wider reach. However, the disadvantages are increased potential for plagiarism, signal strength problems, and sometimes inadequate support for facilities (Irfan et al., 2020).

Learning mathematics aims to help students master important skills such as predictive abilities, mental calculations, representing mathematical information in various ways, and problem-solving (Uslu & Güner, 2022). Therefore, a pre-service math teacher needs to carry out learning with technology. Pre-service teachers should upgrade their knowledge and skills regarding the use of technology to be able to attend lectures during the pandemic. However, the mastery of mathematics pedagogy and content is not as good as the mastery of technology. Even pre-service math teachers need to master math topics well to transfer knowledge to students (Aini, 2021).

Ideally, using technology positively affects math learning, such as increasing students' interest, ease of math understanding, and making it easier for students to learn conceptual and procedural knowledge (Uslu & Güner, 2022). However, due to the lack of technology mastery by lecturers and students before the pandemic, the delivery of math topics was not optimal. As mentioned in previous research, higher education institutions that face limitations or are inexperienced in online learning certainly conquer problems, especially when lecturers are less skilled in operating online apps (Irfan et al., 2020).

Lecturers' obstacles in math lectures include presenting math topics involving math equations and programming languages and a lack of skills in editing videos or animation using apps or software (Irfan et al., 2020). Online mathematics lectures are carried out via video conferencing with the help of blackboards to make it easier for lecturers to write and explain the material that involves mathematical symbols and equations (Cassibba et al., 2020; Johns & Mills, 2021). Learning becomes effective with quality assignments, effective feedback, and actual assignments (Schult et al., 2022). More effective online learning should focus on cognitive activation, student support, and classroom management (Schult et al., 2022).

During the pandemic, microteaching learning practices were also held online, which provided a different atmosphere when students practiced teaching online. Microteaching has been shown to positively influence building connections between theory and practice in the classroom, which provides opportunities for pre-service teachers to practice the theory and teaching skills they learn (Kokkinos, 2022). However, online microteaching also has drawbacks, namely, causing anxiety, technical problems regarding online tools, and difficulties in making learning videos (Rahayu & Sulistyawati, 2022; Kokkinos, 2022).

CONCLUSION

Online lectures attended by pre-service math teacher students affected increasing TK because they should upgrade their technology skills to attend lectures. However, the constraints on lecturers delivering content and using digital devices mean CK is not as good as TK. In addition, PK is also not optimal because, in microteaching courses, learning practices are carried out online, so they have to adapt when teaching offline at school. Considering that digitalization in learning will continue to be carried out and developed, further research can be carried out to find solutions to weak content and pedagogical knowledge in online learning.

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