Journal on Mathematics Education
Volume 15, No. 4, 2024, pp. 1219-1250

Factors shaping Indonesian preservice math teachers' digital media adoption in online mathematics teaching practice: An instrument development and validation study

Naufal Ishartono[1,*], Siti Hajar binti Halili[2], Rafiza binti Abdul Razak[2], Adi Jufriansah[3]

[1]Department of Mathematics Education, Universitas Muhammadiyah Surakarta, Surakarta, Indonesia
[2]Department of Curriculum and Instructional Technology, University of Malaya, Kuala Lumpur, Malaysia
[3]Department of Physics Education, Universitas Muhammadiyah Maumere, Maumere, Indonesia
*Correspondence: naufal.ishartono@ums.ac.id

Received: 11 August 2024 | Revised: 31 October 2024 | Accepted: 15 November 2024 | Published Online: 16 November 2024

Abstract

Numerous studies have examined the development of instruments to identify factors influencing preservice teachers' integration of technology in teaching practices. However, limited research has been dedicated to designing instruments specifically tailored to assess mathematics preservice teachers' integration of Digital Mathematics Learning Media (DMLM) during online teaching practice. This gap is particularly pertinent in the Indonesian context, where assessing future teachers' competencies is crucial. Addressing this gap, the present study endeavors to develop and validate an instrument to identify the factors influencing Indonesian Preservice Mathematics Teachers' (PSMTs) integration of DMLM in online teaching practice. The instrument's theoretical foundation is derived from the Technological Pedagogical Content Knowledge (TPACK) framework, with an emphasis on the Math-TPACK domain, and the Theory of Planned Behavior, focusing on beliefs related to DMLM and online learning. The research employed the ADDIE model for instrument development, combined with Exploratory Factor Analysis (EFA), involving a sample of 303 Indonesian preservice mathematics teachers. The study resulted in the development of a questionnaire comprising 59 indicators across four domains: Math-TPACK, Beliefs on Online Learning, Beliefs on DMLM, and the Use of DMLM. This instrument provides a robust tool for policymakers and educators to identify critical factors affecting PSMTs' effectiveness in online mathematics teaching. Additionally, it offers insights for designing targeted interventions to enhance the quality of online teaching practices.

Keywords: ADDIE, Digital Mathematics Learning Media, Exploratory Factor Analysis, Item-CVI, Scale-CVI

How to Cite: Ishartono, N., Halili, S. H., Razak, R. A., & Jufriansah, A. (2024). Factors shaping Indonesian preservice math teachers' digital media adoption in online mathematics teaching practice: An instrument development and validation study. *Journal on Mathematics Education, 15*(4), 1219–1250. https://doi.org/10.22342/jme.v15i4.pp1219-1250

Online learning has emerged as a primary alternative for educators to deliver instructional materials effectively (Luu, 2021). The Covid-19 pandemic significantly accelerated the adoption of this model in early 2020, compelling educational institutions worldwide to transition to online platforms. Although the pandemic has been officially declared over in many countries (World Health Organization, 2023), online learning continues to be widely utilized as a substitute for traditional face-to-face instruction (Kaufmann & Vallade, 2022). Despite the pandemic's conclusion, this model remains a prevalent choice, owing to its numerous benefits and inherent challenges.

The flexibility of online learning allows educators to conduct lessons from any location and at any time (Aliyyah et al., 2020; Izmirli & Sahin Izmirli, 2015). Additionally, it offers significant advantages to students, including enhanced comfort during learning, active participation in the learning process, improved self-efficacy, and the ability to meet diverse educational needs (Tareen & Haand, 2020). However, several studies have highlighted its limitations, particularly the difficulty of effectively teaching certain subjects, such as mathematics, through online platforms (Khanal et al., 2022; Lumbantoruan & Nadeak, 2022).

For centuries, there has been no universal consensus on the definition of mathematics (Brandt et al., 2016). However, mathematics is often closely associated with the study of numbers, quantity, structure, space, and change (White-Fredette, 2004). These elements function as abstract working objects, leading to the characterization of mathematics as the study of abstract concepts (Benis-Sinaceur, 2014). Consequently, teaching mathematics in an online setting presents significant challenges, as not all students possess the same level of abstraction skills (Hazzan & Kramer, 2016). This necessitates the use of digital media by educators to convey mathematical concepts effectively.

However, this reliance on digital tools introduces additional challenges, particularly for teachers—especially senior educators—who may lack proficiency in using digital media for online instruction (Nailufar et al., 2021). Technical obstacles, such as difficulties in writing mathematical symbols and proofs digitally, further compound these issues. Additionally, students often express dissatisfaction with teachers' pedagogical and professional competence in online environments (Lumbantoruan & Male, 2022). These challenges can hinder and disrupt students' comprehension of mathematical concepts taught online.

Beyond technical issues, online teaching requires teachers to adapt their classroom management strategies and assessment methods, which differ significantly from traditional offline practices. As a result, mastering online teaching skills has become essential for mathematics educators, particularly preservice teachers, who represent the next generation of mathematics instructors.

Preservice Mathematics Teachers (PSMTs) are individuals currently enrolled in teacher education programs or training designed to prepare them for teaching mathematics (da Ponte & Chapman, 2015). These future educators are in the process of acquiring the knowledge, skills, and pedagogical strategies necessary to effectively teach mathematics to students at various educational levels (Djannah et al., 2024; Ratih et al., 2021). As part of their professional readiness, PSMTs must be equipped to teach mathematics in diverse conditions, including online learning environments. A critical skill they must develop is the ability to use Digital Mathematics Learning Media (DMLM), such as GeoGebra, MATLAB, SPSS, and Geometer Sketchpad, to convey mathematical concepts comprehensively. Previous studies have demonstrated that digital learning media significantly enhance the quality of material delivery during online instruction (Ishartono, Nurcahyo, Waluyo, Prayitno, et al., 2022; Minea-Pic, 2020; Van Acker et al., 2013). These competencies can be cultivated through teaching practice courses offered in Professional Teacher Training Programs (PTTPs) across universities.

Regarding the integration of Information and Communication Technology (ICT), particularly digital learning media, by Preservice Teachers (PSTs) during teaching practice, numerous studies have identified factors influencing their intention to incorporate ICT into their instruction. Habibi et al. (2022) investigated the factors affecting the use of ICT by Indonesian preservice teachers during teaching practice and found that subjective norms were the strongest predictors of their intention to use ICT. Similarly, Sadaf et al. (2016) examined American PSTs' integration of Web 2.0 tools during teaching practice, revealing that perceived usefulness, self-efficacy, and student expectations were the primary factors influencing both intention and actual usage. Kalonde and Mousa (2016) explored the technology-related decisions of 90 American teacher educators in methods courses, identifying several influencing factors, including accessibility, content relevance, ease of use, cost, technology training, prior experience, time constraints, technical support, and knowledge gaps.

Despite these findings, no studies have specifically examined the factors influencing preservice mathematics teachers' integration of digital mathematics learning media during online teaching practice. This represents a critical research gap, as understanding these factors is essential for designing effective programs to develop online mathematics teaching skills. Addressing this gap would enable stakeholders to better support PSMTs in mastering the use of digital tools for mathematics instruction, thereby improving the overall quality of online education.

As a result, this study addresses the question of what factors influence PSMTs use of DMLM during online teaching practice. Instead of directly answering this question, the research focuses on the development and validation of an instrument designed to identify these factors. This approach is considered a crucial preliminary step in the broader process of determining the influencing factors.

The primary objective of this study is to design and validate an instrument capable of identifying the factors that impact PSMTs' integration of DMLM during online teaching practice. The study draws on two theoretical frameworks: Technological Pedagogical Content Knowledge (TPACK) and the Theory of Planned Behavior (TPB). These frameworks were chosen based on their established relevance in previous research investigating similar constructs (Habibi et al., 2020, 2022; Sadaf et al., 2016; Yusop et al., 2021). By leveraging these frameworks, the study aims to provide a robust foundation for identifying and analyzing the factors influencing PSMTs' use of DMLM, contributing to the development of effective strategies for improving online mathematics instruction.

TPACK for Technological Integration in Education

The TPACK framework, introduced by Koehler et al. (2009), serves as a comprehensive model for integrating technology into teaching practices by combining three core elements: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). This framework provides educators with a structured approach to designing effective, technology-infused instruction (Hilton, 2016). By bridging these domains, TPACK encourages educators, teacher trainers, and educational technologists to reevaluate and innovate how they employ technology in educational settings to ensure an optimal balance between engaging pedagogy, meaningful content, and appropriate technology use (Cox & Graham, 2009).

The TPACK framework is often depicted as a circular model comprising seven interconnected areas. It begins with the three primary knowledge domains—TK, PK, and CK—and extends to three intersections: Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), and Technological Content Knowledge (TCK). At the center lies TPACK, the convergence of all three domains, as shown in Figure 1.

Schmidt et al. (2009) describe TPACK as a valuable tool for understanding the knowledge teachers require to integrate technology effectively into their instruction. Its potential impact is particularly significant for designing training and professional development programs for both preservice and in-service teachers. Similarly, Niess (2011) emphasizes that TPACK represents the synthesis of subject matter expertise, pedagogical strategies, and technological tools. This integration involves understanding how to represent concepts using technology in ways that make them accessible to students. Mishra and Koehler (2008) further detail four key components of TPACK integration, such as pedagogical techniques that leverage technology effectively to teach content, strategies for making complex concepts more comprehensible, awareness of students' prior knowledge and epistemological perspectives, and the use of technology to build upon existing knowledge and facilitate new understandings.

This holistic approach allows educators to combine pedagogical, content, and technological elements, simplifying complex ideas into formats students can easily grasp. It supports the development of adaptable, pragmatic, and comprehensive instructional methods that incorporate technology effectively (Koehler et al., 2009).

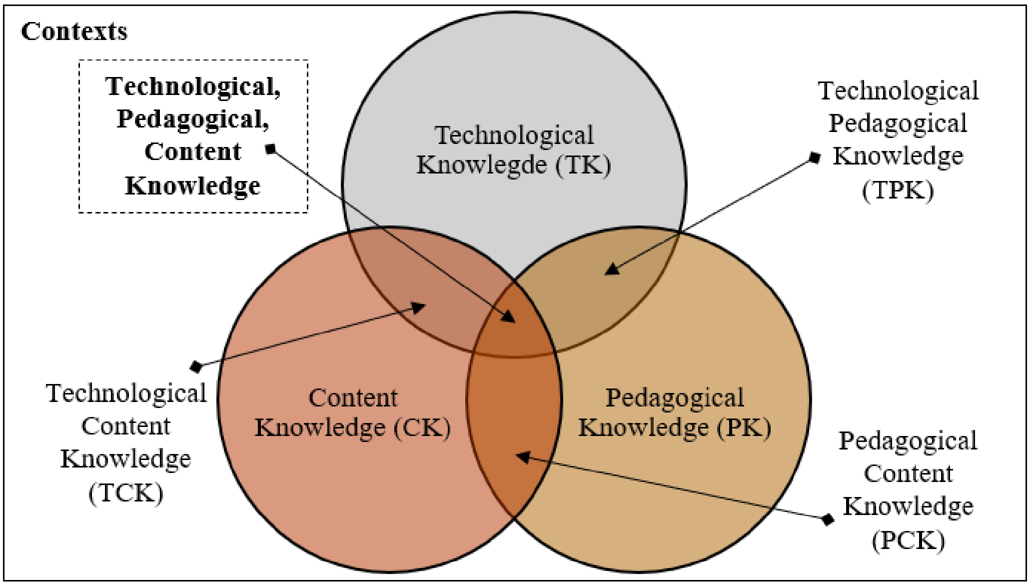

Figure 1. The TPACK framework (Koehler et al., 2009)

In this study, the TPACK framework is adapted to include a specific focus on mathematics, resulting in the Math-TPACK framework, which represents the first alternative factor explored. Math-TPACK integrates mathematical elements into each core component of TPACK. In this model:

1. TK pertains to the use of DMLM, such as GeoGebra, SPSS, Desmos, MATLAB, and similar software.
2. PK includes approaches and models specific to mathematics education, such as ethnomathematics, realistic mathematics education, and numeracy strategies.
3. CK covers school-level mathematics topics, including geometry, algebra, basic statistics, and arithmetic.

The Math-TPACK framework serves as a conceptual foundation for examining how preservice mathematics teachers integrate technology, pedagogy, and content knowledge to enhance their instructional practices in mathematics.

TPB for Technological Integration in Education

TPB is a technology adoption framework that relies on belief-based measurements to understand the intention or use of technology (Ajzen, 1991). This theory is an extension of the Theory of Reasoned Action (TRA)—developed by Fishbein et al. (1980)—which refers to the rational decision for a teacher's intention to use or the actual use based on personal and social factors. What distinguishes the two theories is that the TPB raise the Perceived Behavioral Control (PBC) factor as an additional factor of TRA, which is seen as also affecting how a person perceives technology. This factor indicates whether a person believes the technology to be used has significant convenience or difficulty for them (Habibi et al., 2022). In addition to the TPB, another framework often used by previous research to measure teachers' beliefs in integrating technology is the Technology Acceptance Model (TAM) developed by Davis (1989). Both TAM and TPB predicted intention to use and is quite well, with TAM having a slight empirical advantage. TAM is easier to apply, but only supplies very general information on users' opinions about a system. TBP, on the other hand, provides more specific information that can better guide development (Mathieson, 1991). Therefore, this study uses TPB as a framework to measure the Indonesian PSMTs' beliefs on DMLM based on a study conducted by Sadaf et al. (2012), and to measure PSMTs' beliefs on online learning as what have been done by Mouloudj et al. (2021).

The TPB framework used in this study adapts from that developed by Habibi et al. (2022) which contains three components, namely Attitude (AT), Subjective Norms (SN), and PBC. AT is a factor that motivates someone to do something. While SN is associated with the subjective norm, which defines how other influential and essential people accept and understand the behaviors suggested to be performed. Lastly, PCB is a set that deals with the presence or absence of requisite resources and opportunities (Ajzen, 1991). In this study, TPB became the basis for the formation of two alternative factors besides Math-TPACK, namely Beliefs in DMLM and Beliefs in Online Learning (OL), so that in total there are three alternative factors used in this study which is summarized into a proposed conceptual framework (see Figure 2).

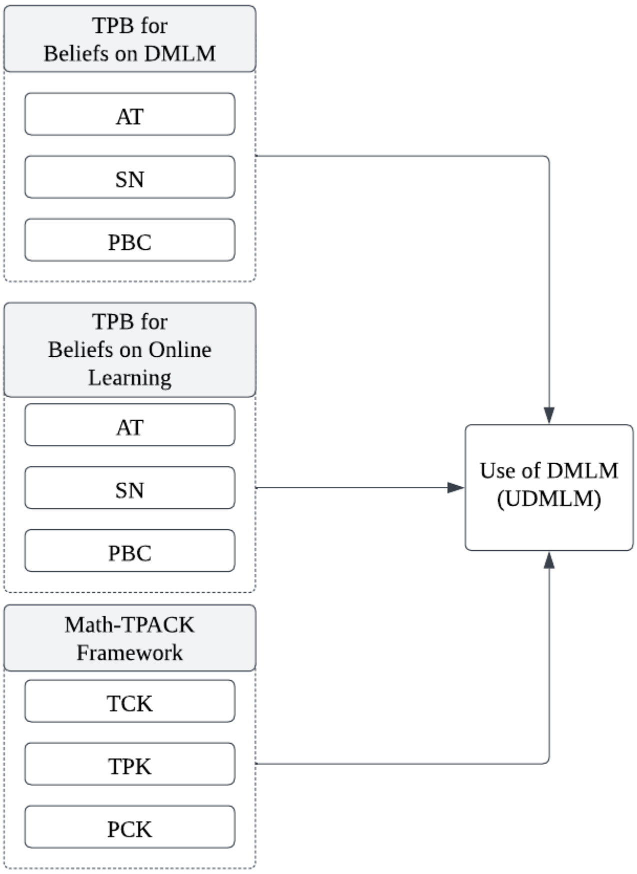

Figure 2. Proposed conceptual framework

The Existing Instruments

Several prior studies have investigated the factors influencing Indonesian preservice teachers' integration of technology during their teaching practice (Yusop et al., 2021; Habibi et al., 2020). For instance, Yusop et al. (2021) examined the factors affecting Indonesian preservice teachers’ technological integration during teaching practice using the TPB as a framework. The findings confirmed that TPB is a valid model for explaining Indonesian PSTs use of ICT during teaching practice. The instrument employed in the study was adapted from those developed in previous research. Similarly, Habibi et al. (2020) explored the role of the TPACK framework in influencing ICT integration among Indonesian preservice language teachers during teaching practice. The study revealed that the components of TPACK are interconnected and that TPACK serves as a valid model for explaining preservice language teachers' use of ICT. The instruments used in this research were also adapted from earlier studies.

Despite these findings, neither of the studies specifically focused on Indonesian preservice teachers' online teaching practices, particularly in the context of mathematics education. This gap is significant, as findings in this area could support institutions, especially mathematics education departments, in designing teaching practice programs that equip preservice teachers with the necessary skills to teach mathematics online. Consequently, it is crucial to investigate the factors influencing Indonesian preservice mathematics teachers’ use of digital mathematics learning media in online teaching practice.

One critical aspect of conducting such research is the selection and development of appropriate data collection instruments. Drawing on the approaches of prior studies, this research employs a survey methodology. The data collection instrument—a questionnaire—is developed based on two theoretical frameworks: TPACK and TPB (Scheuren, 1948). The central research question guiding this study seeks how to comprehensively explore the structured process of developing a survey instrument and evaluate its resulting quality when designed using the theoretical foundations of the TPACK and TPB frameworks. Accordingly, the purpose of this study is to describe the development process and evaluate the quality of the survey instrument grounded in the TPACK and TPB theoretical frameworks.

METHODS

Research Design

This study employs a Research and Development (R&D) approach utilizing the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) development model (Branch, 2009). The selection of this model is attributed to the straightforward and systematic nature of the ADDIE stages (Ishartono, Nurcahyo, Waluyo, Razak, et al., 2022). The detailed development steps are presented in Table 1.

Table 1. Research design

Development Steps	Activities	Data Analysis Technique
Analysis	This step was done by doing literature review on the following factors: • TPACK • Beliefs on DMLM • Beliefs on OL	Qualitative: Descriptive

Development Steps	Activities	Data Analysis Technique
Design	This step was done by designing the construction of the questionnaire based on the analysis step.	
Development	This step was done by the following sub-steps: • Generating Items • Translating Items • Expert Judgement • Readability Test	• Qualitative: Descriptive • Quantitative: I-CVI and S-CVI (Polit et al., 2007)
Implementation	This step was done by implementing the instruments to the research subjects.	-
Evaluation	This step was done by evaluating the result of the Implementation steps.	• Qualitative: Description • Quantitative: Exploratory Factor Analysis (EFA) (Thompson, 2004; Williams et al., 2010)

Research Participants and Sampling Technique

The research participants were involved during the implementation phase, where they were required to provide responses to a distributed questionnaire. The participants comprised Indonesian preservice mathematics teachers from four universities across three provinces in Indonesia. These universities were accredited as "Excellent" by the Indonesian Ministry of Higher Education (MoHE). The qualifications for participant selection were as follows, participants had either completed or were currently undergoing a teaching practice program (microteaching) at their respective universities, the mathematics education department of their universities held an "Excellent" accreditation status, and participants had prior experience with online-based courses during their studies.

The study employed a randomized convenience sampling technique, a non-probability sampling method in which the sample is drawn from a group of individuals who are easily accessible (Tafli, 2021). A total of 303 participants were recruited, exceeding the minimum requirement of 300 participants for conducting Exploratory Factor Analysis (EFA), as recommended by Williams et al. (2010), which categorizes this sample size as adequate. Recruitment took place in November 2023, adhering to ethical research standards outlined by the American Psychological Association (2017). Furthermore, ethical clearance for this study was obtained through an approval letter issued by the University of Malaya, with the reference number TNC 2/UMREC.

Instrumentation

Danielsen et al. (2015) emphasized that the quality of a questionnaire can be assessed through validity and reliability tests. Accordingly, the validity testing of the questionnaire in this study was conducted in two stages: internal and external validity tests. Both tests were performed during the development phase, whereas reliability testing was conducted based on the results from the evaluation phase.

The validity test utilized a validation sheet that assessed three key aspects: construction, technical, and content validity (Jenny & Diesinger, 2011). The validation sheet comprised two sections: a quantitative section and a qualitative section. The quantitative section included response columns rated on a four-point Likert scale (strongly disagree, disagree, agree, and strongly agree). The qualitative section, on the other hand, provided a paragraph field for experts to offer improvement suggestions.

Data Analysis Technique

This study utilized two types of data: qualitative and quantitative. Qualitative data were derived from expert suggestions during the internal validation process and user feedback during the pilot study. These data were analyzed descriptively to enhance the quality of the developed questionnaire. Quantitative data were collected through two processes. First, during the internal validation process, the data consisted of expert assessments recorded on validation sheets, which were analyzed using Inter-Class Correlation (ICC) (Zhang et al., 2019) and the Content Validity Index (CVI) (Polit et al., 2007). Second, during the implementation phase, quantitative data were analyzed using EFA. Statistical tools such as SPSS and Microsoft Excel were employed to perform these analyses.

Exploratory Factor Analysis (EFA) in TPACK and TPB

In this study, EFA is employed to derive the most accurate data from the study population to facilitate the development of new constructs (Osborne, 2015). The construct under development is grounded in two theoretical frameworks: TPACK and TPB. The focus of the construct is on factors influencing Indonesian mathematics teachers' use of DMLM during online teaching practice. The threshold values and requirements for conducting EFA, as outlined by Hair et al. (2019), are summarized in Table 2.

Table 2. Summary of EFA requirement of the threshold value

Measure	Description	Cut off points
Sphericity Bartlett Test (p)	Bartlett's (1951) sphericity test determines if a matrix (of correlations) differs considerably from an identity matrix. The test determines the likelihood that the correlation matrix contains substantial correlations between at least some of the variables in a dataset, which is required for factor analysis.	<.001
KMO	The Kaiser-Meyer-Olkin (KMO) test is a statistical tool used to identify whether data is suitable for factor analysis. The test assesses sampling adequacy for each variable in the model and the overall model.	>.800
Factor Loading	The factor loading represents the correlation between the item and the factor; a factor loading greater than 0.70 generally implies a high connection between the item and the factor.	≥.700
Communalities	The sum of the squared loadings on a factor matrix for a specific item represents the proportion of variation explained by the factors for that specific item. This is referred to as communality. The greater the communality score, the better the retrieved components explain the item's variation.	≥.300
Eigenvalue	Eigenvalues reflect the entire amount of variation that a specific main component can explain. In theory, they can be positive or negative, but they always explain positive variance.	≥1.00

RESULTS AND DISCUSSION

Analysis Stage

The analysis stage involved a comprehensive literature review of the theoretical frameworks of TPACK proposed by Mishra and Koehler (2008) and TPB introduced by Ajzen (1985). The review specifically focused on two key aspects: Beliefs on OL and DMLM. The primary objective of the literature review was to identify relevant indicators that could be incorporated into the development of the questionnaire. The findings from the literature review of TPACK and TPB frameworks are summarized in Table 3.

Table 3. Domains, constructs, definition and reference of questionnaire construct

Domains	Constructs	Definition	References of Indicators to be Adapted
TPACK	Technological Knowledge (TK)	Knowledge of emerging technologies for DMLM integration during online mathematics teaching practice	(Schmidt et al., 2009)
	Content Knowledge (CK)	Knowledge of teaching, such as teaching principles, students' psychology of students, teaching strategies, and management of class during online mathematics teaching practice	(Chai et al., 2010; Luik & Suviste, 2018)
	Pedagogical Knowledge (PK)	Subject matter knowledge, e.g., algebra, calculus, geometry, statistic, and numbering knowledge during online mathematics teaching practice	(Schmidt et al., 2009)
	Pedagogical Content Knowledge (PCK)	Knowledge of changing specific content into an understandable and accessible form for learners via and approach of pedagogy during online mathematics teaching practice	(Schmidt et al., 2009)
	Technological Content Knowledge (TCK)	Knowledge of integrating emerging technologies for specific subject matter knowledge which excludes pedagogical aims during online mathematics teaching practice	(Schmidt et al., 2009)
	Technological Pedagogical Knowledge (TPK)	Knowledge of integrating emerging technologies in pedagogy during online mathematics teaching practice	(Chai et al., 2010; Luik & Suviste, 2018)
	Technological Pedagogical Content Knowledge (TPACK)	Knowledge of implementing technologies to improve students' understanding and learning in specific subject matter knowledge during online mathematics teaching practice	(Chai et al., 2010; Luik & Suviste, 2018; Schmidt et al., 2009)
Beliefs on DMLM	Attitude (AT-DMLM)	Attitude (AT) is a construct to see the attitude of the PSMTs in seeing DMLM in terms of positive and negatives point of view.	(Habibi et al., 2022; Sadaf et al., 2012; Yusop, 2015)
	Subjective Norms (SN-DMLM)	Subjective Norm (SN) is a construct to see how the PSMTs environment supports the use of DMLM in mathematics teaching practice.	(Habibi et al., 2022; Teo & Beng Lee, 2010; Valtonen et al., 2020)

Domains	Constructs	Definition	References of Indicators to be Adapted
	Perceived of Behavioral Control (PBC-DMLM)	Perceived Behavioral Control (PBC) is a construct to see the mastery of the PSMTs in DMLM used in teaching mathematics.	(Habibi et al., 2022; Sadaf et al., 2012; Yusop, 2015)
Beliefs on Online Learning	Attitude (AT-OL)	Attitude (AT) is a construct to see the attitude of the PSMTs in seeing online learning mode in terms of positive and negatives point of view.	(Mouloudj et al., 2021)
	Subjective Norms (SN-OL)	Subjective Norm (SN) is a construct to see how the PSMTs environment supports online learning in mathematics teaching practice.	
	Perceived of Behavioral Control (PBC-OL)	Perceived Behavioral Control (PBC) is a construct to see the mastery of the PSMTs in online learning used in teaching mathematics.	

Table 3 presents the references utilized in developing the indicators before they were translated into specific questionnaire items. For the theoretical framework of TPACK, the work of Schmidt et al. (2009) was the most frequently referenced source, serving as the primary basis for adapting items within the TPACK construct. In the construct of Beliefs on DMLM, the studies by Habibi et al. (2022), Sadaf et al. (2012), and Yusop (2015) were the predominant references used to define and describe the relevant indicators. Finally, for the construct of Beliefs on OL, the study by Mouloudj et al. (2021) was the sole reference adapted to inform the development of the indicators in this category.

Design Stage

The analysis stage identified four key constructs: Math-TPACK, Beliefs on DMLM, Beliefs on OL, and The Use of Digital Mathematics Learning Media (UDMLM). These constructs were further developed into 14 indicators: TK, CK, PK, TCK, PCK, TPK, TPCK, AT-OL, SN-OL, PBC-OL, AT-DMLM, SN-DMLM, PBC-DMLM, and UDMLM. To ensure robust triangulation, each indicator was assigned at least two questions, which were adapted from established references listed in Table 3 and contextualized to align with mathematical education.

The questionnaire was designed with three sections for clarity and comprehensiveness. The first section includes a consent form, allowing respondents to voluntarily indicate their agreement to participate. The second section collects demographic information, including gender, university accreditation, experience with online lectures, and experience with the use of digital mathematics learning media. The third section comprises the core questions targeting the 14 indicators, with responses captured using a five-point Likert scale ranging from 0 (Strongly Disagree) to 4 (Strongly Agree).

To ensure the validity and quality of the questionnaire, an instrument was developed based on Creswell's (2014) principles of content, construct, and face validity. This instrument consists of two components: a quantitative scoring section using an even-numbered Likert scale and a qualitative feedback section that allows experts to provide suggestions for improvement. The validity testing was conducted during the Development stage, specifically in the internal validity phase, involving expert evaluations. This comprehensive approach ensures the questionnaire is both reliable and reflective of the constructs it aims to measure.

Development Stage

This phase began with the development of indicators for each construct, guided by the adaptation of instruments from prior research (as detailed in Table 3). A total of 68 indicators were initially generated, with each construct comprising four to seven items. The subsequent step involved constructing a questionnaire based on insights obtained during the design phase. To ensure validity, the questionnaire underwent an internal validity assessment conducted by six experts, all holding PhDs in education. These experts were selected based on their extensive experience in factor analysis research and their roles as primary authors in Scopus-indexed publications related to factor analysis within the past five years.

The internal validity assessment yielded two types of results: quantitative findings and qualitative feedback from expert evaluations. The process began with an analysis of the qualitative feedback provided by the experts, which formed the basis for refining the questionnaire. Based on this feedback, four indicators were removed, reducing the total to 64 indicators. Following the revisions, the instrument was reviewed and discussed with five Indonesian preservice mathematics instructors, selected based on their qualifications, which included teaching experience and participation in online courses during their studies. The instructors reported no technical issues with the questionnaire, confirming its clarity and usability. Consequently, the final questionnaire retained 64 indicators as shown in Table 4.

Table 4. The different versions of the domains during the validation process

Domains	Version 1[a]		Version 2[b] (64 indicators)		Version 3[c] (64 indicators)	
	Construct	**Number of Indicators**	**Construct**	**Number of Indicators**	**Construct**	**Number of Indicators**
Math-TPACK	TK	5	TK	3	TK	3
	CK	4	CK	4	CK	4
	PK	6	PK	6	PK	6
	PCK	5	PCK	5	PCK	5
	TCK	5	TCK	4	TCK	4
	TPK	4	TPK	4	TPK	4
	TPACK	5	TPACK	5	TPACK	5
Beliefs on DMLM	AT	5	AT	5	AT	5
	SN	4	SN	4	SN	4
	PBC	4	PBC	4	PBC	4
Beliefs on OL	AT	5	AT	5	AT	5
	SN	4	SN	4	SN	4
	PBC	5	PBC	5	PBC	5
UDMLM	-	7	-	6	-	6
Total		68		64		64

[a] Before the expert evaluation as a result of phase 1

[b] Phase 2 (discussion with six experts)

[c] Phase 3 (discussion with five users)

The quantitative results of the internal validity assessment were analyzed using the Content Validity Index (CVI) formula, implemented through Microsoft Excel. The CVI is categorized into two types: Item-CVI (I-CVI) and Scale-CVI (S-CVI) (Polit & Beck, 2006). According to Lynn (1986) and Polit and Beck (2006), an I-CVI score of at least 0.83 is required when involving six experts in the assessment.

The CVI analysis results, presented in Table 5, demonstrate that the I-CVI for all factors is 1, indicating that every item in the designed instrument is deemed significant by the experts. Furthermore, the Universal Agreement (UA) value for all factors is also 1, reflecting that expert ratings consistently ranged between 3 (agree) and 4 (strongly agree). Additionally, the S-CVI/Ave and S-CVI/UA values for all aspects were both calculated as 1. These results confirm that all items in the instrument meet the theoretical criteria for acceptability.

Table 5. CVI result

Domains	AA	EA	I-CVI	I-CVI Category	UA	S-CVI/Ave	S-CVI/UA
Math-TPACK	QI	6	1	Relevant	1	1	1
	FL	6	1	Relevant	1		
	EU	6	1	Relevant	1		
Beliefs on DMLM	QI	6	1	Relevant	1	1	1
	FL	6	1	Relevant	1		
	EU	6	1	Relevant	1		
Beliefs on OL	QI	6	1	Relevant	1	1	1
	FL	6	1	Relevant	1		
	EU	6	1	Relevant	1		
UDMLM	QI	6	1	Relevant	1	1	1
	FL	6	1	Relevant	1		
	EU	6	1	Relevant	1		

Note: AA = Assessed Aspect; EA = Expert in Agreement; Ave = Average; UA = Universal Agreement; QI = The statement follows the questionnaire indicators; FL = Statement using the formal language; EU = Statements are seen as easy to understand by respondents

Following this validation, the indicators selected for implementation are summarized in Table 6. To ensure accessibility and ease of distribution, the finalized questionnaire was converted into a Google Form, allowing respondents to complete it online efficiently.

Table 6. Indicators for Math-TPACK, Beliefs on DMLM, Beliefs on OL, and UDMLM

Domain	Constructs	Number of Indicator	Indicators
Math-TPACK	Technological Knowledge (TK)	3	TK1, TK2, TK3
	Content Knowledge (CK)	4	CK1, CK2, CK3, CK4
	Pedagogical Knowledge (PK)	6	PK1, PK2, PK3, PK4, PK5, PK6
	Technological Content Knowledge (TCK)	5	TCK1, TCK2, TCK3, TCK4, TCK5

Domain	Constructs	Number of Indicator	Indicators
	Pedagogical Content Knowledge (PCK)	4	PCK1, PCK2, PCK3, PCK4
	Technological Pedagogical Knowledge (TPK)	4	TPK1, TPK2, TPK3, TPK4
	Technological Pedagogical Content Knowledge (TPACK)	5	TPACK1, TPACK2, TPACK3, TPACK4, TPACK5
Beliefs on DMLM	Attitude (AT)	5	DMLM_AT1, DMLM_AT2, DMLM_AT3, DMLM_AT4, DMLM_AT5
	Subjective Norm (SN)	4	DMLM_SN1, DMLM_SN2, DMLM_SN3, DMLM_SN4
	Perceived of Behavioral Control (PBC)	4	DMLM_PBC1, DMLM_PBC2, DMLM_PBC3, DMLM_PBC4
Beliefs on Online Learning	Attitude (AT)	5	OL_AT1, OL_AT2, OL_AT3, OL_AT4, OL_AT5
	Subjective Norm (SN)	4	OL_SN1, OL_SN2, OL_SN3, OL_SN4
	Perceived of Behavioral Control (PBC)	5	OL_PBC1, OL_PBC2, OL_PBC3, OL_PBC4, OL_PBC5
UDMLM		6	UDMLM 1, UDMLM 2, UDMLM 3, UDMLM 4, UDMLM 5, UDMLM 6,

Implementation Stage

The implementation phase began in January 2023 with the submission of permission letters to the heads of mathematics education departments at 14 universities across Indonesia. These universities were selected based on their integration of digital mathematics learning media into their courses and their experience in conducting online lectures. The selected universities spanned seven provinces and were located on five different islands within Indonesia, ensuring geographical diversity.

Table 7. Demographic information of the respondents

n. 303			
Demography	**Responses**	**Frequency**	**Percentage (%)**
Gender	Male	149	49%
	Female	154	51%
University Accreditation	Accredited A	182	60%
	Not Accredited A	121	40%
DMLM-Based Class	Under 2 classes	136	45%
	2 classes above	167	55%

By the end of January 2023, all required permissions were obtained from department heads and deans at the respective institutions. Subsequently, the questionnaire was distributed, and responses were collected from 325 participants by the end of March 2023. The extended data collection period was primarily due to communication challenges and limitations in facilities from both student and departmental perspectives. The collected data were analyzed using SPSS 23, focusing on identifying and removing outliers. This process led to the exclusion of 22 outliers, resulting in 303 valid responses for subsequent analysis. The demographic characteristics of the respondents are summarized in Table 7, providing an overview of the study population.

Evaluation Stage

The collected data were analyzed using SPSS 23, beginning with a normality test by examining the skewness values. According to Garson (2012), data are considered normally distributed if the skewness values fall within the range of -2 to +2. A more stringent criterion by Hair et al. (2010) asserts that data are normal if skewness values are between -1 and +1. Following the normality test, a reliability analysis was conducted. Pallant (2020) suggests that an indicator is deemed reliable if its Cronbach's Alpha value is at least 0.600. The results of the normality and reliability tests are summarized in Table 8. The skewness values for all four domains were found to be within the -1 to +1 range, confirming the normality of the data distribution. Additionally, the Cronbach's Alpha values for all four domains exceeded 0.600, indicating that the data are reliable for further analysis.

Table 8. The value of Skewness, Kurtosis, and Cronbach's Alpha for Math-TPACK, Beliefs on DMLM, Beliefs on OL, and UDMLM

Domain	N	Skewness		Kurtosis		Reliability (α)	
		Min	Max	Min	Max	Min	Max
Math-TPACK	303	-0.461	0.098	-0.372	0.379	0.866	0.940
Beliefs on DMLM	303	-0.225	-0.018	-0.233	0.474	0.785	0.895
Beliefs on Online Learning	303	-0.094	-0.004	-0.731	-0.218	0.876	0.958
UDMLM	303	-0.273		-0.141		0.930	

Next is the analysis of KMO to identify whether data is suitable for factor analysis. The test assesses sampling adequacy for each variable in the model and the overall model with cut off value is ≥ 0.800. Besides, another test is Bartlett's Test of Sphericity which determines the likelihood that the correlation matrix contains substantial correlations between at least some of the variables in a dataset, which is required for factor analysis with cut off value is < 0.001. The result of both analyses can be seen in Table 9. It presents the results of the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity for four domains: Math-TPACK, Beliefs on DMLM, Beliefs on OL, and UDMLM. The KMO values range from 0.779 to 0.870, indicating that the data for all domains is suitable for factor analysis. Specifically, the KMO values for Math-TPACK (0.843), Beliefs on DMLM (0.784), Beliefs on OL (0.870), and UDMLM (0.779) suggest good to very good sampling adequacy, with all values comfortably exceeding the commonly accepted threshold of 0.7. While Bartlett's Test of Sphericity shows significant results ($p < 0.001$) across all domains, further confirming that the variables within each domain are sufficiently correlated for factor analysis. The approximate Chi-Square values vary, reflecting the differences in the scales and number of variables, with Math-TPACK showing the highest Chi-Square (11112.961) and UDMLM the lowest (1572.894). These results indicate that the instrument used in this study is appropriate for exploring the underlying factor structure within these domains, providing a solid foundation for further analysis.

Table 9. KMO and Bartlett's test of Math-TPACK, Beliefs on DMLM, Beliefs on OL, and UDMLM

Domain	KMO Measure for Sampling Adequacy	Bartlett's Test of Sphericity		
		Approx. Chi-Square	df	Sig.
Math-TPACK	0.843	11112.961	465	0.000
Beliefs on DMLM	0.784	2499.330	78	0.000
Beliefs on OL	0.870	5005.230	91	0.000
UDMLM	0.779	1572.894	15	0.000

The subsequent analysis concentrated on three key metrics: Communalities, Eigenvalue, and Factor Loading, across the four domains. The Communalities test evaluates the extent to which an item shares variance with other items within the factor analysis framework. It quantifies the proportion of variance in each observed variable explained by the extracted common factors, with a cut-off value of ≥ 0.300 being considered acceptable (Osborne, 2015). Factor Loading analysis assesses the correlation strength between each item and its respective factor. A loading value exceeding 0.700 is generally considered indicative of a strong relationship between the item and the corresponding factor (Thompson, 2004).

Additionally, Eigenvalue analysis examines the total amount of variance accounted for by each principal component. Eigenvalues represent the positive variance attributed to a factor, providing an indication of its significance within the dataset (Kieffer, 1999). While theoretically capable of assuming both positive and negative values, Eigenvalues in practice represent only positive variance. The results of these analyses are summarized in Table 10, with Eigenvalue results for the four domains further illustrated through a Scree Plot in Figure 3. This comprehensive analysis ensures a robust understanding of the relationships and variances among the observed variables within the study.

Table 10. Communalities, Eigenvalue, and Loading Factor of Math-TPACK, Beliefs on DMLM, Beliefs on OL, and UDMLM

Domain	Communalities		Eigenvalue			Factor Loading		
	Min	Max	Min	Max	Counted Construct	Min	Max	Dropped Indicators
Math-TPACK	0.726	0.942	1.238	11.238	All	0.712	0.912	TCK4 (0.630)
Beliefs on DMLM	0.494	0.849	1.554	5.784	All	0.717	0.874	DMLM_PBC1 (0.579), DMLM_SN1 (0.519), DMLM_SN4 (0.677)
Beliefs on OL	0.752	0.899	1.006	8.756	All	0.728	0.832	OL_SN1 (0.619)
UDMLM	0.656	0.833	4.447		All	0.810	0.912	-

The analysis of Communalities, as presented in Table 10, highlights the degree to which each item shares variance with other items within its respective domain. For the Math-TPACK domain, communalities range from 0.726 to 0.942, indicating a strong shared variance among the items, suggesting that the extracted factors effectively explain a substantial portion of the variance for each item.

In the Beliefs on DMLM domain, the communalities range from 0.494 to 0.849, reflecting a moderate to high level of shared variance among the items. This suggests that while some items are more closely related to the common factors, all items demonstrate sufficient shared variance to justify their inclusion in the construct. Furthermore, the Beliefs on OL domain exhibits communalities between 0.752 and 0.899, indicating a consistently strong shared variance among its items. This high level of shared variance underscores the coherence and reliability of the items within this domain. Lastly, the UDMLM domain shows communalities ranging from 0.656 to 0.833, indicating a high level of shared variance among the items. These results collectively affirm that the extracted factors across all domains account for a significant proportion of the variance, supporting the validity and robustness of the constructs measured.

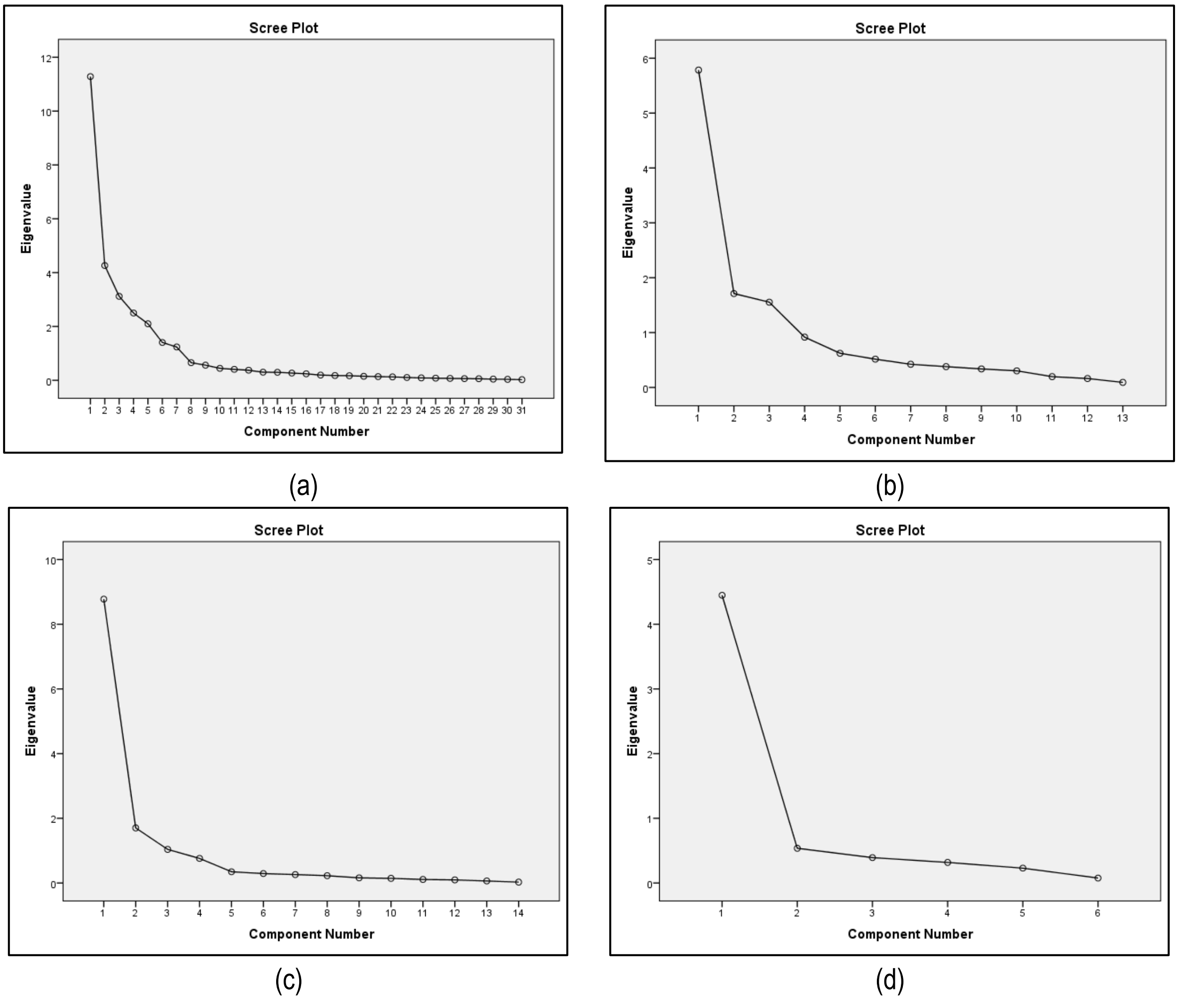

Figure 3. Scree plot of (a) Math-TPACK, (b) Beliefs on DMLM, (c) Beliefs on OL, and (d) UDMLM

In terms of Factor Loading, which measures the correlation between each item and its respective factor, the Math-TPACK domain has values ranging from 0.712 to 0.912, indicating a high correlation. However, one indicator, TCK4, has a lower loading value of 0.630, which, while acceptable, suggests a weaker relationship with the factor compared to other items. The Beliefs on DMLM domain has factor loadings ranging from 0.717 to 0.874, with specific indicators such as DMLM_PBC1, DMLM_SN1, and

DMLM_SN4 having lower loadings, indicating moderate correlations. The Beliefs on OL domain shows strong factor loadings between 0.728 and 0.832, though OL_SN1 has a slightly lower loading of 0.619. In the UDMLM domain, the factor loadings are very strong, ranging from 0.810 to 0.912, reflecting robust correlations between the items and their factors. The Eigenvalue analysis indicates that all factors are significant, with values exceeding 1.0, highlighting the importance of each factor in explaining the variance within the respective domains. The results of Eigenvalue are additionally supported by the Scree Plot visualization, which depicts each domain in Figure 3. All Scree Plots demonstrate that the constructions of each domain are more than 1.00. This signifies that all constructs have been declared approved.

Discussion

The purpose of this study is to describe the development process and quality of the questionnaire to measure the skills of the Indonesian preservice mathematics teachers in integrating mathematics digital technology during their online mathematics teaching practice. The questionnaire development process is based on the ADDIE development model which includes steps to analyze the needs of instruments based on the results of the literature review and questionnaire quality, the results of the design stage that focus on the design of the questionnaire along with validation instruments based on the results of the analysis stage, the development stage which aims to develop and validate the questionnaire (using Content Validity Index / CVI analysis), the implementation stage that focuses on in the field test on the quality of the questionnaire, as well as the evaluation stage which uses Exploratory Factor Analysis (EFA). A summary of the development process can be seen in Table 11 where in general of the 64 indicators tested, three indicators and five indicators were declared unfeasible and left 59 indicators that are suitable for use based on the Loading Factor value in Table 10.

Table 11. Final indicators after EFA

Construct	Number on Indicators	EFA Result	Dropped Indicators
TK	3	3	-
CK	4	4	-
PK	6	6	-
PCK	5	5	-
TCK	4	3	1 (TCK4)
TPK	4	4	-
TPACK	5	5	-
AT-DMLM	5	5	-
SN-DMLM	4	2	2 (SN1 & SN4)
PCB-DMLM	4	3	1 (PBC1)
AT-OL	5	5	-
SN-OL	4	3	1(SN 1)
PCB-OL	5	5	-
UDMLM	6	6	-
Total	64	59	5

These findings align with previous studies that have employed EFA in the development of questionnaires. For instance, Durdu and Dağ (2017) designed a questionnaire to assess preservice teachers' TPACK development and conceptions through a TPACK-based course, building upon the research conducted by Kaya and Dağ (2013). In their study, they evaluated reliability using Cronbach's Alpha, achieving a score of 0.770, which confirmed the instrument's reliability. Additionally, EFA was utilized to refine and select the indicators included in the questionnaire.

Similarly, Jamieson-Proctor et al. (2013) developed the Teaching Teachers for the Future (TTF) TPACK survey instrument, a questionnaire that was adapted from the instrument created by Albion et al. (2010). Reliability testing using Cronbach's Alpha yielded a score of 0.970, indicating a highly reliable instrument. EFA was also applied to identify and confirm the validity of the indicators used in their instrument. Lastly, Karatas et al. (2017) conducted a study examining the technological pedagogical content knowledge, self-confidence, and perceptions of preservice middle school mathematics teachers regarding instructional technologies. They developed a questionnaire adapted from Schmidt et al. (2009). Reliability was tested using Cronbach's Alpha, which resulted in a score of 0.940, categorizing the instrument as highly reliable. EFA was employed to ensure the selected indicators met the required standards for inclusion in the questionnaire.

In the context of the ADDIE development model employed in designing the questionnaire for the present study, the findings align with previous studies that have utilized the ADDIE model for similar purposes. For example, Santiari (2015) developed a questionnaire to evaluate students' attitudes toward e-learning using the ADDIE instructional design framework. Similarly, Jais et al. (2022) applied the ADDIE model to create a questionnaire assessing the implementation of a self-learning interactive module for Year 5 primary school students.

Based on this analysis, the study's findings suggest that the questionnaire developed is well-suited for identifying the factors influencing Indonesian mathematics preservice teachers' integration of digital mathematics technology during online teaching practices. The combination of the ADDIE model and EFA ensures the questionnaire's robustness and relevance. This instrument can be utilized by Indonesian PTTPs to determine the most significant factors affecting mathematics education students' adoption of digital technology in online teaching scenarios. Furthermore, the identified factors from this study provide a foundation for designing course structures that support and strengthen these critical areas, thereby enhancing the integration of digital mathematics technology in future teaching practices.

CONCLUSION

This study effectively addressed its primary research questions by developing a questionnaire (see Appendix) to identify the factors influencing Indonesian preservice mathematics teachers' integration of digital mathematics learning media during online teaching practices and evaluating the quality of the instrument. Utilizing the integrated ADDIE development model and Exploratory Factor Analysis (EFA), the resulting questionnaire was shown to be both valid and reliable. This instrument provides a valuable tool for understanding the determinants of ICT integration in mathematics education, particularly in the context of online teaching practices among preservice educators in Indonesia.

However, this research has certain limitations that should be acknowledged. The demographic composition of the study sample was restricted exclusively to Indonesian preservice mathematics teachers, limiting the generalizability of the findings to broader, international contexts. Moreover, while the instrument demonstrated reliability and validity, the study was constrained by the available references and sources used for the development of its indicators. Expanding these references could have enriched the quality and scope of the questionnaire's design.

To address these limitations and advance research in this area, future studies should consider testing this instrument with preservice mathematics teachers from diverse cultural, country, and educational backgrounds to ensure its applicability across different contexts. Expanding the sample size could enhance the robustness of the Exploratory Factor Analysis results. Additionally, incorporating a broader range of academic references during the instrument development process could improve its comprehensiveness. Such steps would strengthen the validity of future research and provide deeper insights into the global integration of ICT in mathematics education.

Acknowledgments

The authors express their gratitude to the heads of the mathematics education departments from 14 universities for their invaluable support during the data collection process. Additionally, the authors extend their appreciation to the University of Malaya, Malaysia, for issuing the ethical clearance letter (Ref. No: TNC 2/UMREC) and to Universitas Muhammadiyah Surakarta for funding this study through the Hibah Integrasi Tridharma (HIT) Batch 4 for the 2023/2024 academic year, under Grant ID: 3024.

Declarations

Author Contribution	:	NI: Conceptualizing, Writing, Data Collecting, Methodology, and Formal Analysis. SHH: Review, Validation, and Supervision. RAR: Review, Validation, and Supervision. AJ: Methodology, Formal Analysis, and Editing.
Finding Statement	:	The study was funded by Universitas Muhammadiyah Surakarta under a research grant Hibah Integrasi Tridharma (HIT) Batch 4 2023/2024 with ID: 3024.
Conflict of Interest	:	The authors declare no conflict of interest

REFERENCES

Ajzen, I. (1985). *From intentions to actions: A theory of planned behavior*. In Action control. https://doi.org/10.1007/978-3-642-69746-3_2

Ajzen, I. (1991). *Theory of Planned Behavior*. In Organizational Behavior and Human Decision Processes. Academic Press. https://doi.org/10.1080/10410236.2018.1493416

Albion, P., Jamieson-Proctor, R., & Finger, G. (2010). Auditing the TPACK confidence of Australian pre-service teachers: The TPACK confidence survey (TCS). *Proceedings of Society for Information Technology Teacher Education International Conference 2010, 11*(3), 3772–3779. http://www.editlib.org/p/33969

Aliyyah, R. R., Reza, R., Achmad, S., Syaodih, E., Nurtanto, M., Sultan, A., Riana, A., & Tambunan, S. (2020). The Perceptions of Primary School Teachers of Online Learning during the COVID-19 Pandemic Period : A Case Study in Indonesia. *Journal of Ethnic and Cultural Studies, 7*(2), 90–109. https://doi.org/10.29333/ejecs/388

American Psychological Association. (2017). Ethical Principles of Psychologists and Code of Conduct. https://www.apa.org/ethics/code

Bartlett, M. S. (1951). The effect of standardization on a χ 2 approximation in factor analysis. *Biometrika*, *38*(3/4), 337-344. https://doi.org/10.2307/2332580

Benis-Sinaceur, H. (2014). *Facets and Levels of Mathematical Abstraction*. In Philosophia Scientae (Issues 18–1). https://doi.org/10.4000/philosophiascientiae.914

Branch, R. M. (2009). *Instructional Design: The ADDIE Approach*. Springer. https://doi.org/10.1007/978-0-387-09506-6

Brandt, J., Lunt, J., & Meilstrup, G. R. (2016). Mathematicians' and Math Educators' Views on "Doing Mathematics." *Primus, 26*(8), 753–769. https://doi.org/10.1080/10511970.2016.1166408

Chai, C. S., Koh, J. H. L., & Tsai, C.-C. (2010). Facilitating Preservice Teachers' Development of Technological, Pedagogical, and Content Knowledge (TPACK). *Educational Technology & Society, 13*(4), 63–73. https://www.jstor.org/stable/jeductechsoci.13.4.63

Cox, B. S., & Graham, C. R. (2009). Using an Elaborated Model of the TPACK Framework to Analyze and Depict Teacher Knowledge. *TechTrends, 53*(5), 60–71. https://doi.org/10.1007/s11528-009-0327-1

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (sixth). Sage Publisher. https://doi.org/10.5539/elt.v12n5p40

da Ponte, J. P., & Chapman, O. (2015). Preservice mathematics teachers' knowledge and development. In *Handbook of International Research in Mathematics Education* (Issue 10872). https://doi.org/10.4324/9780203930236.ch11

Danielsen, A. K., Pommergaard, H.-C., Burcharth, J., Angenete, E., & Rosenberg, J. (2015). Translation of Questionnaires Measuring Health Related Quality of Life Is Not Standardized: A Literature Based Research Study. *PLOS ONE, 10*(5), e0127050. https://doi.org/10.1371/journal.pone.0127050

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly: Management Information Systems, 13*(3), 319–339. https://doi.org/10.2307/249008

Djannah, M., Ishartono, N., Hayuni, A. A., Mufidah, A., Firdaus Bin Sufahani, S., & Waluyo, M. (2024). Exploring Ethnomathematical Geometry in Indonesian Shadow Puppetry Gunungan: Philosophical and Educational Implications. *Jurnal Varidika, 36*(1), 110–125. https://doi.org/10.23917/varidika.v36i1.5661

Durdu, L., & Dağ, F. (2017). Pre-Service Teachers' TPACK Development and Conceptions through a TPACK-Based Course. *Australian Journal of Teacher Education, 42*(11), 150–171. https://doi.org/10.14221/ajte.2017v42n11.10

Fishbein, M., Jaccard, J., Davidson, A. R., Ajzen, I., & Loken, B. (1980). Predicting and understanding family planning behaviors. In *Understanding attitudes and predicting social behavior*. Prentice Hall. https://nyuscholars.nyu.edu/en/publications/predicting-and-understanding-family-planning-behaviors

Garson, G. D. (2012). *Testing statistical assumptions: Blue Book Series*. In Asheboro: Statistical Associate Publishing. https://www.researchgate.net/profile/Jurandy_Penitente-Filho/post/What_is_the_best_statistical_method_to_correlate_immunohistochemestry_and_rtpcr/attachment/59d61d9879197b807797853c/AS:271755204071424@1441802897825/download/assumptions.pdf

Habibi, A., Razak, R. A., Yusop, F. D., Muhaimin, M., Asrial, A., Mukminin, A., & Jamila, A. (2022). Exploring the factors affecting pre-service science t eachers ' actual use of technology during teaching practice. *South African Journal of Education, 42*(1), 1–11. https://www.ajol.info/index.php/saje/article/view/229350

Habibi, A., Yusop, F. D., & Razak, R. A. (2020). The Role of TPACK in Affecting Pre-Service Language Teachers' ICT Integration during Teaching Practices: Indonesian Context. *Education and Information Technologies, 25*(3), 1929–1949. https://doi.org/10.1007/s10639-019-10040-2

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate Data Analysis* (Seventh). https://www.pdfdrive.com/multivariate-data-analysis-7th-edition-e156708931.html

Hair, J. F., Sarstedt, M., & Ringle, C. M. (2019). Rethinking some of the rethinking of partial least squares. *European Journal of Marketing, 53*(4), 566–584. https://doi.org/10.1108/EJM-10-2018-0665

Hazzan, O., & Kramer, J. (2016). Assessing Abstraction Skills: What Makes a Good Question?. *Communications of the ACM, 59*(12), 43–45. https://doi.org/10.1145/2926712

Hilton, J. T. (2016). A Case Study of the Application of SAMR and TPACK for Reflection on Technology Integration into Two Social Studies Classrooms Integration into Two Social Studies Classrooms. *The Social Studies, 7996*(February), 68–73. https://doi.org/10.1080/00377996.2015.1124376

Ishartono, N., Nurcahyo, A., Waluyo, M., Prayitno, H. J., & Hanifah, M. (2022). Integrating Geogebra Into the Flipped Learning Approach To Improve Students ' Self-Regulated Learning During the Covid-19 Pandemic. *Journal on Mathematics Education, 13*(1), 69–85. https://doi.org/10.22342/jme.v13i1.pp69-86

Ishartono, N., Nurcahyo, A., Waluyo, M., Razak, R. A., Sufahani, S. F., & Hanifah, M. (2022). GeoGebra-based flipped learning model: An alternative panacea to improve student's learning independency in online mathematics learning. *JRAMathEdu (Journal of Research and Advances in Mathematics Education), 7*(3), 178–196. https://doi.org/10.23917/jramathedu.v7i3.18141

Izmirli, S., & Sahin Izmirli, O. (2015). Factors motivating preservice teachers for online learning within the context of ARCS motivation model. *Turkish Online Journal of Distance Education, 16*(2), 56–68. https://doi.org/10.17718/tojde.26620

Jais, N. F. M., Ishak, S. A., & Md Yunus, M. (2022). Developing the Self-Learning Interactive Module using ADDIE Model for Year 5 Primary School Students. *International Journal of Academic Research in Progressive Education and Development, 11*(1), 615–630. https://doi.org/10.6007/IJARPED/v11-i1/11919

Jamieson-Proctor, R., Albion, P., Finger, G., Cavanagh, R., Fitzgerald, R., Bond, T., & Grimbeek, P. (2013). Development of the TTF TPACK survey instrument. *Australian Educational Computing, 27*(3), 26–35. https://www.learntechlib.org/p/133312/

Jenny, J. Y., & Diesinger, Y. (2011). Validation of a French version of the Oxford knee questionnaire. *Orthopedics and Traumatology: Surgery and Research, 97*(3), 267–271. https://doi.org/10.1016/j.otsr.2010.07.009

Kalonde, G., & Mousa, R. (2016). Technology Familiarization to Preservice Teachers. *Journal of Educational Technology Systems, 45*(2), 236–255. https://doi.org/10.1177/0047239515616965

Karatas, I., Tunc, M. P., Yilmaz, N., & Karaci, G. (2017). An investigation of technological pedagogical content knowledge, self-confidence, and perception of pre-service middle school mathematics teachers towards instructional technologies. *Educational Technology and Society, 20*(3), 122–132. https://www.jstor.org/stable/26196124

Kaufmann, R., & Vallade, J. I. (2022). Maximizing the student experience: moving forward with online learning. *Communication Education, 71*(2), 152–154. https://doi.org/10.1080/03634523.2021.2022730

Kaya, S., & Dağ, F. (2013). Turkish adaptation of Technological Pedagogical Content Knowledge Survey for elementary teachers | Sinif Öğretmenlerine Yönelik Teknolojik Pedagojik İçerik Bilgisi Ölçegi'nin Türkçeye Uyarlanmasi. *Kuram ve Uygulamada Egitim Bilimleri, 13*(1), 302–306. https://eric.ed.gov/?id=EJ1016741

Khanal, B., Joshi, D. R., Adhikari, K. P., & Khanal, J. (2022). Problems of Mathematics Teachers in Teaching Mathematical Content Online in Nepal. *International Journal of Virtual and Personal Learning Environments, 12*(1). https://doi.org/10.4018/IJVPLE.312845

Kieffer, K. M. (1999). An Introductory Primer on the Appropriate Use of Exploratory and Confirmatory Factor Analysis. *Research in the Schools, 6*(2), 75–92. https://eric.ed.gov/?id=EJ610713

Koehler, M. J., Mishra, P., & Cain, W. (2009). What is Technological Pedagogical Content Knowledge (TPACK)? *Journal of Education, 193*(3), 13–19. https://doi.org/10.1177/002205741319300303

Luik, P., & Suviste, R. (2018). Perceptions of technological, pedagogical and content knowledge (TPACK) among pre-service teachers in Estonia. *Educ Inf Technol, 23*, 741–755. https://doi.org/10.1007/s10639-017-9633-y

Lumbantoruan, J. H., & Male, H. (2022). Impact of Unprepared Competence and Difficulty in Competence of Mathematics Teachers During Online Learning. *JTAM (Jurnal Teori Dan Aplikasi Matematika), 6*(4), 876. https://doi.org/10.31764/jtam.v6i4.9164

Lumbantoruan, J. H., & Nadeak, B. (2022). Mathematics teacher competency analysis during online learning. *International Journal of Trends in Mathematics Education Research, 5*(2), 214–221. https://doi.org/10.33122/ijtmer.v5i2.132

Luu, H. N. Q. (2021). Learners' Perceptions towards Online Learning during the Covid-19 Pandemic: A Study at a Center of Foreign Languages in Vietnam. *Vietnam Journal of Education, 5*(3), 84–90. https://doi.org/10.52296/vje.2021.124

Lynn, M. R. (1986). Determination and quantification of content validity. *Nursing Research, 35*(6), 382–386. http://ijoh.tums.ac.ir/index.php/ijoh/article/view/26

Mathieson. (1991). Comparing The Technology Acceptance Model with The Theory of Planned Behaviour. *Information Systems Research, 2*(3), 173–191. https://doi.org/10.1287/isre.2.3.173

Minea-Pic, A. (2020). Innovating teachers' professional learning through digital technologies. *OECD Education Working Papers, 237*(237), 42. https://eric.ed.gov/?id=ED609836

Mishra, P., & Koehler, M. J. (2008). Introducing Technological Pedagogical Content Knowledge. Paper Presented at the *Annual Meeting of the American Educational Research Association*, 1–16. https://www.scirp.org/reference/referencespapers?referenceid=1565931

Mouloudj, K., Bouarar, A. C., & Stojczew, K. (2021). Analyzing the Students' Intention to Use Online Learning System in the Context of COVID-19 Pandemic: A Theory of Planned Behavior Approach. In W. James, C. Cobanoglu, & M. Cavusoglu (Eds.), *Advances in Global Education and Research* (Vol. 4, pp. 1–17). https://doi.org/10.5038/9781955833042

Nailufar, Y., Safruddin, S., & Zain, Moh. I. (2021). Analysis of Teacher Difficulties in Online Learning on Mathematics Subjects. *Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram, 9*(2), 280. https://doi.org/10.33394/j-ps.v9i2.4376

Niess, M. L. (2011). Investigating TPACK: Knowledge growth in teaching with technology. *Journal of Educational Computing Research, 44*(3), 299–317. https://doi.org/10.2190/EC.44.3.c

Osborne, J. W. (2015). What is rotating in exploratory factor analysis? Practical Assessment, *Research and Evaluation, 20*(2), 1–7. https://doi.org/10.7275/hb2g-m060

Pallant, J. (2020). *SPSS survival manual: A step by step guide to data analysis using IBM SPSS*. Routledge. https://doi.org/10.4324/9781003117452

Polit, D. F., & Beck, C. T. (2006). The Content Validity Index: Are You Sure You Know What's Being Reported? Critique and Recommendations. *Research in Nursing & Health, 29*, 489–497. https://doi.org/10.1002/nur

Polit, D. F., Beck, C. T., & Owen, S. V. (2007). Is the CVI an Acceptable Indicator of Content Validity? Appraisal and Recommendations. *Research in Nursing & Health, 30,* 459–467. https://doi.org/10.1002/nur

Ratih, K., Fahmi, M., Syah, J., Jarin, S., & Buckworth, J. (2021). Learning Pattern during the Disruptive Situation in Informal Education: Parents' Efforts and Challenges in the Adjustment of Progressive Learning. *Ijolae, 3*(3), 180–193. https://doi.org/10.23917/ijolae.v3i3.15151

Sadaf, A., Newby, T. J., & Ertmer, P. A. (2012). Exploring pre-service teachers' beliefs about using Web 2.0 technologies in K-12 classroom. *Computers and Education, 59*(3), 937–945. https://doi.org/10.1016/j.compedu.2012.04.001

Sadaf, A., Newby, T. J., & Ertmer, P. A. (2016). An investigation of the factors that influence preservice teachers' intentions and integration of Web 2.0 tools. *Educational Technology Research and Development, 64*(1), 37–64. https://doi.org/10.1007/s11423-015-9410-9

Santiari, N. P. L. (2015). Embed Attitude from Student on Elearning Using Instructional Design with ADDIE Model. *International Journal of Advanced Computer Science and Applications, 6*(11), 35–43. https://doi.org/10.14569/IJACSA.2015.061105

Scheuren, B. F. (1948). *What is a Survey*. 1–68. https://fweil.com/

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological Pedagogical Content Knowledge (TPACK): The Development and Validation of an Assessment Instrument for Preservice Teachers. In *Journal of Research on Technology in Education (Vol. 123*). https://doi.org/10.1080/15391523.2009.10782544

Tafli, T. (2021). A Comparative Study on TPACK Self-Efficacy of Prospective Biology Teachers from the Faculties of Education & Science. *International Journal of Curriculum and Instruction, 13*(3), 2957–2980. https://eric.ed.gov/?id=EJ1312866

Tareen, H., & Haand, M. T. (2020). International Journal of Advanced Research and Publications A Case Study of UiTM Post-Graduate Students' Perceptions on Online Learning: Benefits & Challenges. *International Journal of Advanced Research and Publications, 4*(6), 86–94. https://www.scirp.org/reference/referencespapers?referenceid=3026904

Teo, T., & Beng Lee, C. (2010). Explaining the intention to use technology among student teachers: An application of the Theory of Planned Behavior (TPB). *Campus-Wide Information Systems, 27*(2), 60–67. https://doi.org/10.1108/10650741011033035

Thompson, B. (2004). *Exploratory and confirmatory factor analysis: Understanding concepts and applications*. In Washington, DC (Vol. 10694, Issue 000). https://doi.org/10.1080/10705510802339122

Valtonen, T., Leppänen, U., Hyypiä, M., Sointu, E., Smits, A., & Tondeur, J. (2020). Fresh perspectives on TPACK: pre-service teachers' own appraisal of their challenging and confident TPACK areas. *Education and Information Technologies, 25*(4), 2823–2842. https://doi.org/10.1007/s10639-019-10092-4

Van Acker, F., van Buuren, H., Kreijns, K., & Vermeulen, M. (2013). Why teachers use digital learning materials: The role of self-efficacy, subjective norm and attitude. *Education and Information Technologies, 18*(3), 495–514. https://doi.org/10.1007/s10639-011-9181-9

White-Fredette, K. (2004). *What Is Mathematics? An Exploration of Teachers' Philosophies of Mathematics During A Time of Curriculum Reform* (Issue 1). Georgia State University. https://www.proquest.com/openview/2f14bce075e5c23361c70f443745b083/1?pq-origsite=gscholar&cbl=18750

Williams, B., Onsman, A., & Brown, T. (2010). *Exploratory factor analysis: A five-step guide for novices*. Australasian Journal of Paramedicine. https://ajp.paramedics.org/index.php/ajp/article/view/93

World Health Organization. (2023). *WHO chief declares end to COVID-19 as a global health emergency*. UN News. https://news.un.org/en/story/2023/05/1136367

Yusop, F. D. (2015). A dataset of factors that influence preservice teachers' intentions to use Web 2.0 technologies in future teaching practices. *British Journal of Educational Technology, 46*(5), 1075–1080. https://doi.org/10.13140/2.1.4587.5026

Yusop, F. D., Habibi, A., & Razak, R. A. (2021). Factors Affecting Indonesian Preservice Teachers' Use of ICT During Teaching Practices Through Theory of Planned Behavior. *SAGE Open, 11*(2). https://doi.org/10.1177/21582440211027572

Zhang, M., Zhang, H., Li, J., Wang, L., Fang, Y., & Sun, J. (2019). Supervised graph regularization based cross media retrieval with intra and inter-class correlation. *Journal of Visual Communication and Image Representation, 58*, 1–11. https://doi.org/10.1016/j.jvcir.2018.11.025

Appendix

Questionnaire Factors Influencing Mathematics Education Study Program Students in Integrating Technology in Online Mathematics Learning Practice

This questionnaire aims to collect data related to the responses of mathematics education study program students, who are prospective mathematics teachers, related to the integration of technology in mathematics teaching practices carried out online. The participant profile of this questionnaire is a student of the 7th semester mathematics education study program. The aspects assessed from this study are the TPACK aspect, Beliefs on Digital-based Mathematics Education, Beliefs on Online Learning, and demographic aspects. The grid of the water questionnaire is as follows:

Aspect	Point	Number of Items	Definition
TPACK	TK	4	Technology Knowledge (TK) is the teacher's knowledge of a technology and how and when it is used in the learning process (Matthew J. Koehler et al., 2009). Meanwhile, Zelkowski et al., (2013) define kindergarten as teachers' knowledge of technology and its relationship with learning. In this context, TK refers to PSMT Indonesia's knowledge of DMLM software.
	PK	3	Pedagogical Knowledge (PK) is a teaching method and process and includes knowledge in classroom management, assessment, lesson plan development, and student learning (Schmidt et al., 2009). In this study, PK refers to the knowledge of PSMT Indonesia about the learning models, approaches and methods they use during the practice of teaching online mathematics.
	CK	4	Content Knowledge (CK) is the teacher's knowledge of the material he will teach (Matthew J. Koehler et al., 2009). In this context, CK refers to PSMT Indonesia's knowledge of mathematics as content including algebra, basic statistics, geometry, and arithmetic.
	TPK	3	Pedagogical Knowledge of Technology (TPK) is the teacher's knowledge about the use of technology integrated with pedagogical theories (learning models, approaches, and strategies) to achieve a learning goal (Koehler et al., 2009). TPK in this study refers to the knowledge of PSMT Indonesia on how to integrate technological knowledge with pedagogical knowledge during online mathematics teaching practice
	TCK	3	Technology Content Knowledge (TCK) is the understanding of how technology and content affect and limit each other (Koehler et al., 2009). This suggests that teachers understand that, by using certain technologies, they can change the way learners practice and understand concepts within specific content areas (Schmidt et al., 2009). In this study, TCK is the knowledge of PSMT Indonesia about the use of DMLM to solve problems and

			understand topics related to including algebra, basic statistics, geometry, and arithmetic.
	PCK	3	Pedagogical Content Knowledge (PCK) is the teacher's knowledge about the proper use of pedagogical theories to teach valid learning materials (Koehler et al., 2009). This component is the basic knowledge that every teacher must master (C. R. Graham, 2011). This component was promoted by Shulman (1986) before being modified by Koehler. This knowledge is very much possessed by teachers and even PST in Indonesia (Chieng & Tan, 2021). In this study, PCK refers to the knowledge of PSMT Indonesia in choosing the right learning approach to teach algebra, basic statistics, geometry, or arithmetic well.
	Math-TPACK	3	Math-TPACK refers to PSMT Indonesia's knowledge in integrating DMLM—as part of a learning model—to teach algebra, basic statistics, geometry, or arithmetic correctly during online math teaching practices.
TPB: Beliefs on DMLM	AT	4	Attitude (AT) is a factor that motivates a person to integrate DMLM
	SN	3	Subjective Norm (SN) is associated with subjective norms, which define how influential and other essential people accept and understand DMLM integration.
	PCB	3	Perceived Control Beliefs (PCB) are a set that relates to the presence or absence of resources and opportunities required in using DMLM.
TPB: Beliefs on Online Learning	AT	3	Attitude (AT) is a factor that motivates a person to teach math online
	SN	3	Subjective Norm (SN) is associated with subjective norms, which define how influential and other essential people receive and understand online math teaching practices
	PCB	3	Perceived Control Beliefs (PCBs) are a set that relates to the availability or absence of resources and opportunities needed in teaching math online
The Use of DMLM		7	The Use of Digital-based Mathematics Learning Media (DMLM) is the process of choosing not only tools but also methods in utilizing DMLM in a learning process.
Demography		8	Demographic analysis studies and measures the dimensions and dynamics of populations; It can include an entire society or group determined by criteria such as education, nationality, religion, and ethnicity

Research Questionnaire

Part 1: Concern Form

I would like to require your help to participate to fill up the survey about the research that I have been doing. The data provided will be kept confidential and will only be used for academic research purposes only. The identifiable information will not be collected and the participants identify will not be disclosed at any form of publication. In addition, participants should be aware that surveys may have little risk and there is no direct benefit to participants. Filling out this questionnaire will take around 15-20 minutes, and your identity is anonymous.

By selecting "I agree", it means that you are a student of mathematics education department, have read and understood the consent form and agree to participate in this survey. Thank you very much for your participations.

a. I Agree
b. I Disagree

Part 2: Demographic Information

1. Gender:
   a. Male
   b. Female

2. How many education/mathematics education/pure mathematics courses are based on or related to mathematics software that you have completed?
   a. 1
   b. 2-3
   c. > 3

3. Have you ever learned math online?
   a. Yes
   b. No

4. Have you implemented the teaching internship integrated Teaching Campus program?
   a. Yes
   b. No

5. University Accreditation
   a. Excellent
   b. Very Good
   c. Good

6. Accreditation of mathematics education study programs
   a. Excellent
   b. Very Good
   c. Good

7. Does your university support online teaching practices in terms of facilities and policies?
   a. Yes
   b. No
   c. Maybe

8. Whether your university requires the lecture process to use technology during online or offline learning?
   a. Yes
   b. No
   c. I do not know

Math-TPACK

Math software: SPSS, Mathlab, GeoGebra, Calculator, Geometer Sketchpad, Desmos, or any other math-related software.

Mathematical concepts: mathematical concepts taught in schools such as geometry, algebra, basic statistics, logic, and arithmetic

Please answer all questions, and if you are unsure or neutral with your response, then you can select "2" which refers to "Between Agree/Disagree". Choose one of the following answer options by crossing (×) or giving sign (✓):

0 = Strongly disagree
1 = Disagree
2 = Neutral
3 = Agree
4 = Strongly Agree

Technological Knowledge

Question	0	1	2	3	4
1. I know how to operate math software as a teaching medium					
2. I know which math software is right to teach math concepts					
3. I know when I should use math software as a teaching medium					

Content Knowledge

Question	0	1	2	3	4
4. I have a good understanding of school math concepts					
5. I can think based on mathematical concepts					
6. I have many ways and strategies in solving problems based on mathematical concepts					
7. I can create problems to evaluate mathematical concepts					

Pedagogical Knowledge

Question	0	1	2	3	4
8. I understand the types of techniques for assessing students' math learning outcomes (Ex: test, interview, portfolio, quiz, etc.)					
9. I understand how to choose a strategy that is in accordance with the mathematics material I teach					
10. I understand how to make a math lesson plan					
11. I understand the types of mathematics learning approaches that are often used (Ex: Ethnomathematics, STEAM, Realistic Mathematics Education, and HOTS)					

12. I understand the types of learning models that are suitable for math learning (Ex: PjBL, PBL, Guided Discovery, etc.)					
13. I understand how to manage good mathematics learning according to the character of students					

Pedagogical Content Knowledge

Question	0	1	2	3	4
14. I can choose a suitable learning approach to teach math concepts					
15. I can choose a suitable learning model to explain mathematical concepts					
16. I can choose the appropriate learning strategy to explain the mathematical concepts					
17. I know how to assess students' understanding of mathematical concepts					
18. I can determine the appropriate materials and learning resources to teach math concepts					

Technological Content Knowledge

Question	0	1	2	3	4
19. I know math software that can help me understand math concepts					
20. I can choose the right math software to visualize math concepts					
21. I can use appropriate math software to solve math concept-based problems					

Technological Pedagogical Knowledge

Question	0	1	2	3	4
22. I can choose math software that suits my learning approach					
23. I can use math software that can support the process of learning mathematics					
24. I can use math software to evaluate students' mathematical understanding					
25. I can create a math lesson plan that integrates math software					

Model of Math-TPACK

Question	0	1	2	3	4
26. I can choose math software that can actively involve students in learning math					
27. I can integrate math software into my learning approach to teach math concepts well					
28. I can help my friend in integrating math software in the practice of teaching mathematics					
29. I can use math software to assess students' understanding of math concepts					
30. I can use math software as a classroom management tool					

Beliefs on DMLM

Attitude

Question	0	1	2	3	4
31. I feel comfortable when teaching using math software					
32. I feel happy when teaching mathematics using mathematics software					
33. I feel that teaching math using math software is a good idea					
34. I feel that using math software has benefited me more than the disadvantages					
35. I feel that using math software can help me in conveying material more easily					

Subjective Norm

Question	0	1	2	3	4
36. My study program supports me to use mathematics software in teaching practice					
37. My lecturer supports me to use mathematics software in teaching practice					

Perceived Behavioral Control

Question	0	1	2	3	4
38. I have high confidence in using math software during teaching					
39. I am always ready to teach mathematics with integrated math software					
40. I feel that it is easy to adapt to various mathematics software as a learning medium					

Beliefs on Online Learning

Attitude

Question	0	1	2	3	4
41. In my opinion, teaching math online is a good idea					
42. I would feel comfortable teaching math online					
43. I would be happy if I taught math online					
44. I feel that online learning provides more benefits than disadvantages					
45. I feel that the online math learning model will help me in communicating the material well					

Subjective Norm

Question	0	1	2	3	4
46. My study program supports and facilitates me if I practice teaching mathematics online					
47. Lecturers will support me if I practice teaching mathematics online					
48. I feel that the people around me have a good perception regarding online math learning					

Perceived Behavioral Control

Question	0	1	2	3	4
49. I feel that there will be no significant obstacles if I teach math online					
50. I have a high level of trust if I teach math online					
51. I feel that I am always ready to carry out online math learning					
52. I find it easy to adapt to the operation of online learning applications such as Zoom, Google Meet, etc.					
53. I find it easy to adapt to the operation of Learning Management Systems (LMS) such as Google Classroom and Schoology					

The Use of DMLM During Online Teaching Practice

If the practice of teaching mathematics is carried out online, then:	0	1	2	3	4
54. I will be able to assess students' mathematical understanding using math software					
55. I will be able to create mathematics teaching materials based on mathematics software					
56. I will be able to create an integrated lesson plan with math software					
57. I will be able to use math software to simulate math concepts					
58. I will be able to use math software to stimulate students in learning math					
59. I will be able to manage classes using an integrated LMS of math software					