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Article

Evaluation of digital technology management in mathematics learning: A sequential explanatory design in Eastern Indonesia

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Abstract

The rapid advancement of digital technology necessitates that teachers enhance their competencies in the teaching and learning process of mathematics. This study aims to evaluate the demographic factors affecting teachers' use of digital technology and their digital skills, explore the frequency of online learning platform usage in relation to teachers' digital skills, and identify challenges while providing recommendations for integrating technology into mathematics instruction through a Sequential Explanatory Design mixed-methods approach. The quantitative sample consisted of 104 mathematics teachers, with 14 teachers selected as respondents for the qualitative phase. Data collection instruments included questionnaires, structured interviews, and non-participant observations, with quantitative data analyzed using Jamovi 2.4.8.0 software, and qualitative data manually coded and thematically analyzed using an inductive-deductive approach. The findings indicate that employment status, teaching experience, and school level significantly influence the use of digital technology in teaching mathematics. Teachers who are government employees under contract, have over 10 years of teaching experience, and teach at the middle or high school level tend to integrate technology more effectively. Consequently, government policies and educational programs for technology development should prioritize teachers irrespective of their employment status, offering continuous training (both online and offline) focused on mathematics.

Keywords: digital technology integration, mathematics education, teacher competencies, sequential explanatory design, digital skills in teaching

Introduction

The Indonesian government is seriously improving the education sector, particularly by integrating digital technology into mathematics learning. This initiative aims to enhance the quality of education and prepare students for the continuously evolving digital era. The role of teachers as learning managers is crucial (Dizon, 2024; Halim et al., 2024), and teachers need the ability to effectively manage learning that utilizes digital technology (Alieto et al., 2024; Cevikbas et al., 2023; Kartal & Çınar, 2024).

The use of digital technology in mathematics learning is not an end goal but a means to achieve better educational outcomes. Mathematics, often perceived as difficult by many students (Beccuti et al., 2023; Pokhrel, 2024; Sen Zeytun et al., 2023; Umayah & Sutama, 2024), can be accessed more effectively through engaging and interactive digital technology (Alieto et al., 2024; Kartal & Çınar, 2024; Le Pichon et al., 2021). Digital technology helps present mathematical concepts visually (Pinter & Siddiqui, 2024; Wen & Yin, 2024), allows students to practice independently, and provides detailed feedback.

Despite the significant potential of digital technology to enhance mathematics learning (Familoni &

Onyebuchi, 2024; Park & Kwon, 2023; Timotheou et al., 2023; Yohannes & Chen, 2023), not all teachers possess the necessary skills and knowledge to integrate it effectively into their teaching. Some challenges faced by teachers in utilizing digital technology in learning include inadequate infrastructure, limited technology access for students, insufficient content-focused training, and unclear curriculum adjustments to technology use (Fowler & Leonard, 2021; Hernández et al., 2023; Huang, 2023; Jacinto & Carreira, 2023).

Our pilot study of qualitative research in high schools revealed that current teachers' main issues are anxiety, lack of experience, and insufficient knowledge about using technology in mathematics lessons, especially integrating relevant technological software. Furthermore, the demands of the independent curriculum mandated by the Ministry of Education through the Ministry of Education and Culture Regulation No. 12 of 2024 entrust teachers to design learning that meets students' needs, including digital literacy. As per the researchers' experience in mentoring mathematics teachers, schools in Eastern Indonesia (Sumbawa Island and Lombok Island) lack adequate facilities and infrastructure, and teachers' activities based on using educational technology are minimal or non-existent. In high schools, computer labs are typically reserved for information technology subjects or practical activities. Integrating digital technology into mathematics emphasizes its importance in enhancing students' critical thinking skills (Clark-Wilson et al., 2020; Hoyles, 2018; Santos-Trigo, 2023).

Thus, to enhance teachers' self-management in integrating digital technology (software and online education platforms) in mathematics learning, a critical evaluation or needs analysis is needed to identify the challenges faced by teachers based on regional characteristics, specifically in Eastern Indonesia, Dompu Regency, West Nusa Tenggara Province, using a sequential explanatory design. Sequential explanatory design allows for exploring unexpected results from previous quantitative studies (Ivankova et al., 2006). This design aims to explore and clarify quantitative findings with qualitative data (Thornberg et al., 2020; Watson et al., 2017), such as identifying factors affecting academic performance in mathematics learning (Bascones et al., 2024).

Based on the explanation above, the research questions are as follows: 1) Is there a relationship between teacher demographics and the use of digital technology in teaching mathematics?; 2) How are digital skills influenced by mathematics teachers' demographics?; 3) Is there a relationship between the frequency of digital technology use in mathematics teaching and digital skills?; 4) What is the relationship between the use of digital technology, frequency of digital technology use, and digital skills?; and 5) What are the challenges and recommendations for teachers in integrating digital technology into mathematics teaching?

The importance of digital technology in education and its challenges

The advancement of digital technology has significantly transformed the educational landscape, particularly in the teaching profession, which now demands digital competence to effectively integrate technology into learning. Teachers are required not only to adapt to digitalization but also to design effective learning environments (Brevik et al., 2019). This competence is crucial for preparing students to navigate an ever-evolving digital society (Johannesen & Øgrim, 2020). Online platforms such as WhatsApp and Google Classroom facilitate collaboration and enhance learning outcomes (Kolesnyk & Biseth, 2024), while social media platforms like Twitter, Facebook, and others enable innovative participation in global issues (Christensen et al., 2021).

However, technological advancements also challenge the current education system, revealing weaknesses in preparing the younger generation (Biseth et al., 2022). Technology, which has become an integral part of daily life, influences human behavior and supports students in seeking information for school tasks (Holmarsdottir et al., 2024). Children and adolescents, often referred to as digital natives, are naturally adept with technology, including its use in education (Seland et al., 2022). Video-based assessment can enhance feedback in teaching practices (Daza et al., 2024), and digital technology has transformed mathematics instruction, encouraging more hands-on approaches (Das, 2021). Technology also plays a vital role in developing students' critical thinking skills (Viberg et al., 2023).

Despite these advances, the implementation of information and communication technology (ICT) in education remains uneven, influenced by socio-economic factors and limited infrastructure (Seland et al., 2022). Teachers face challenges in effectively integrating ICT, including a lack of policy support, inadequate infrastructure, and the need for ongoing professional development (Eickelmann et al., 2022). Furthermore, there is significant variation in teachers' ability to use technology in the classroom, with ICT usage often falling short of expectations (Gudmundsdottir & Hatlevik, 2018). The lack of contextual information in video assessments also poses a challenge (Daza et al., 2024), and the integration of university theory with school practice remains a persistent issue (Brevik et al., 2019). Despite efforts to accelerate educational digitalization, the use of ICT remains limited, particularly due to underdeveloped social aspects and students' fear of mathematics, which hinders the transformation of physical classrooms into virtual ones (Viberg et al., 2023).

Integration of digital technology in education and mathematics teacher management

Electronic devices, tools, resources, and systems such as mobile devices, social media, multimedia, and online resources that generate/receive, process, store, and communicate information are often referred to as Digital Technology. Integrating digital technology in mathematics teaching impacts the education sector globally, including in Indonesia. Digital technology not only broadens access to learning resources but also fundamentally changes teaching methods (Alieto et al., 2024; Fowler & Leonard, 2021; Huda, 2024). In mathematics teaching, digital technology helps make abstract concepts more concrete and visual (Agyei et al., 2023; Koyunkaya & Dede, 2024). The use of digital technology aids teachers in illustrating these concepts interactively (Sevimli, 2023), facilitating more critical and active understanding among students (Mwaniki et al., 2024).

Digital technology has proven to significantly contribute to improving educational outcomes (Thurm et al., 2022) by enhancing teaching and learning capacities. Therefore, teachers' self-management in integrating digital technology is crucial for the successful implementation of technology in teaching. Teachers must possess adequate technical skills to use digital tools, manage digitally based classrooms, design and develop teaching materials, and monitor and evaluate students' learning progress using digital data. Good teacher management in digital technology focuses not only on using technological tools but also on strategies and teaching practices that maximize their use to improve student learning outcomes (Timotheou et al., 2023; Wallace et al., 2022).

Technological Pedagogical Content Knowledge (TPACK)

The framework integrating content, pedagogical, and technological knowledge is commonly known as Technological Pedagogical Content Knowledge (TPACK). TPACK is essential for mathematics teachers to effectively integrate technology (Akyuz, 2018; ÖZEN & KURTULUŞ, 2023; Yildiz & Arpaci, 2024). TPACK emphasizes that effective teaching with technology requires interconnected and mutually supportive knowledge (Bwalya & Rutegwa, 2023). For example, a mathematics teacher should identify technology that can be used to teach specific mathematical concepts in ways that facilitate student understanding while applying effective pedagogical strategies. Thus, TPACK helps teachers design more holistic and meaningful learning experiences for students (Papanikolaou et al., 2017). Various factors can influence the success of integrating technology into mathematics teaching, such as age, gender, teaching experience, and employment status, which can affect teachers' ability and readiness to adopt technology (Orakova et al., 2024; Zulnaidi et al., 2024), availability of infrastructure, and technology accessibility (Alieto et al., 2024; Mwaniki et al., 2024; Rueda-Gómez et al., 2023).

This study utilizes TPACK as a conceptual framework to assess the capabilities of prospective mathematics teachers in effectively integrating technology into their teaching. TPACK has been proven to be an effective evaluation tool for measuring teachers' ability to use technology, as affirmed by previous research (Bernsteiner et al., 2024; Kartal & Çınar, 2022). This evaluation encompasses various aspects, including teachers' attitudes toward technology, the use of artificial intelligence, and the contextual factors influencing the implementation of TPACK in the classroom (Li, 2024). In this context, technology-based assessment, particularly in formative settings, offers opportunities to support individual learners through adaptive systems (Weigand et al., 2024).

However, TPACK has also faced criticism for its tendency to focus more on individual cognitive processes without adequately considering the transfer of knowledge within broader social contexts (Larsen, 2023). Therefore, this study combines the TPACK approach with an emphasis on the social and contextual interactions that influence the successful implementation of technology in the classroom. Adaptive pedagogy also plays a crucial role, especially in regions such as East Indonesia, where limited access to technology and educational infrastructure presents significant challenges (Lahn & Berntsen, 2023). This evaluation aims to identify the needs for developing teachers' digital competence and improving the technological infrastructure necessary to facilitate more effective mathematics learning (Tusiime et al., 2019).

Research methodology

Research design

This study employs a sequential explanatory design (Creswell & Clark, 2017) to generate more constructive concepts and recommendations based on quantitative and qualitative evidence. This design consists of two phases: a quantitative phase followed by a qualitative phase where quantitative data collection and analysis are conducted first, followed by qualitative data analysis (Ivankova et al., 2006). In the quantitative phase, we identify patterns and statistical relationships among variables such as gender, age, teaching experience, employment status, school level, and school location in relation to mathematics teachers' use of digital technology and their digital skills. The qualitative phase then delves deeply into mathematics teachers' perceptions of the challenges and recommendations for integrating technology into teaching, further strengthening and explaining the findings from the quantitative analysis. The results from the quantitative phase are used to focus and deepen the interviews in the qualitative phase. The research was conducted over six months, from December 2023 to May 2024, in Dompu Regency, West Nusa Tenggara Province, Eastern Indonesia.

Quantitative phase

A total of 104 mathematics teachers were selected as research samples using a simple random sampling technique. These teachers, all holding at least a bachelor's degree, teach at senior high schools and junior high schools. Additionally, they include civil servants, government employees with work agreements, and honorary teachers teaching in urban and rural areas. The detailed demographics of the mathematics teachers are presented in Table 1.

Table 1. Sample and demographics of mathematics teachers

Variable	Category	Counts	% of Total (N = 104)
Age	25-34 years	40	38.5%
	35-44 years	36	34.6%
	45-54 years	9	8.7%
	>54 years	19	18.3%
Gender	Male	39	37.5%
	Female	65	62.5%
Employment Status	Honorary Teacher	31	29.8%
	Civil Servant	53	51.0%
	Government Employee with Contractual Work	20	19.2%
Teaching Experience	1-5 years	16	15.4%
	6-10 years	31	29.8%
	>10 years	57	54.8%
School Level	Senior High School	46	55.8%
	Junior High School	58	44.2%
School Location	Urban	58	55.8%
	Rural	46	44.2%

Questionnaire as a research instrument for data collection on the use of digital technology in mathematics lessons. The questionnaire was distributed directly and through Google Forms. It was then sent via e-mail, WhatsApp contacts, and WhatsApp groups for Mathematics Subject Teacher Conferences in the area. The questionnaire was initially tested on 15 mathematics teachers in junior and senior high schools, and reviewed by three experienced experts in mathematics education and instructional technology as well as education practitioners, all holding at least Associate Professor-level position. The experts assessed content validity, and their agreement was measured using the Aiken index, formulated as described by Retnawati (2016).

Formula: $V = \frac{\sum_{i=1}^{n} s_i}{R(c-1)}$

Explanation:

V	index of expert agreement on item validity
$\sum_{i=1}^{n} s_i$	the sum of scores given by each expert is subtracted by the lowest score within the utilized category
R	number of experts
c	number of categories that can be chosen by experts

The interpretation of the V index calculation results can be categorized as follows: if the index is less than or equal to 0.4, the validity is low; if the index is between 0.4–0.8, the validity is moderate; and if the index is greater than 0.8, the validity is high (Retnawati, 2016). Based on the Rj Editor output in Jamovi version 2.4.8.0 for 15 items evaluated by 3 experts, the average Aiken's V was 0.75, which falls under the medium validity category. Furthermore, this study conducted an internal reliability measurement by identifying the Cronbach's Alpha values that correlate with each other and consistently measure the same construct. The criteria from DeVellis and Thorpe (2021) were used in interpreting the Cronbach's Alpha of this research instrument (see Table 2).

Table 2. Criteria for interpreting Cronbach's alpha values

Cronbach's Alpha	Reliability Interpretation
Less than 0.6	Low
0.60 - 0.69	Moderate
0.70 - 0.79	Good
0.80 - 0.89	Very Good
0.90 or higher	Excellent

Based on the output from Jamovi 2.4.8.0, the questionnaire indicated Cronbach’s Alpha value of 0.76. The high mean rating was 2.82, suggesting a tendency for respondents to provide positive ratings. The quantitative data analysis was entirely conducted using Jamovi 2.4.8.0, with descriptive and inferential statistics including Linear Regression and Correlation.

Qualitative phase

Following the quantitative data analysis, some participants were selected using a purposive sampling technique for interviews. Out of the 104 mathematics teachers who participated in the quantitative stage, 14 teachers were selected, comprising 7 teachers each from urban and rural school areas.

Interviews were conducted face-to-face, recorded, and subsequently transcribed. The analysis process involved identifying interview transcript segments, with each respondent assigned a specific code such as initials as shown in Table 3.

The interview data were analyzed using a thematic analysis approach, conducted manually following the procedures outlined by Braun and Clarke (2006). We first thoroughly read the data to understand its content and noted initial ideas. Next, relevant segments of the data were labeled (initial coding). We then grouped the formed codes to identify the main themes. Once the initial themes were identified, we reviewed them to ensure consistency and relevance. The final themes were given descriptive names that reflected the core of the data. The last step involved reporting the themes with a structured narrative and direct quotations from the data to illustrate the issues under investigation.

Table 3. Respondent initials

Level of School	Teacher's Initials	School District
Senior High School	N.	Rural
Senior High School	R.	
Senior High School	S. F.	
Senior High School	F. W.	
Junior High School	S. D.	
Junior High School	H. R.	
Junior High School	S. P. S.	
Senior High School	Z. K.	Urban
Senior High School	S. A.	
Senior High School	H. J.	
Senior High School	M. T. B. S.	
Junior High School	K. R.	
Junior High School	M.	
Junior High School	H. S. S.	

As part of efforts to maintain data validity, the researcher conducted triangulation by comparing the results of quantitative and qualitative analyses. Triangulation was performed twice: first with mathematics teachers, academics, and the research team, and then by validating the findings with participants through Zoom meetings. Additionally, three independent experts provided critical assessments of the analysis results. Drawing on the researchers' extensive experience in publishing and authoring books focused on qualitative research in mathematics teaching, the researchers aimed to explore the richness of data descriptions inductively.

Ethical considerations

The research spanned 6 months, during which the researcher prioritized respondent comfort from the outset. Consequently, the researcher established good communication and rapport with respondents to gain trust, ensuring the acquisition of high-quality and academically accountable data. The study maintained respondent anonymity and confidentiality by using pseudonyms (Lahman et al., 2015), particularly during the qualitative phase in a Sequential Explanatory Design. Understanding the scope of the research through questionnaires and interviews, respondents voluntarily provided consent without pressure from the research team or other parties to explore school conditions. In this regard, respondents also consented via a signed statement.

Results

Quantitative phase

Table 4. Descriptive statistics

	N	Mean	SE	SD
Digital Technology Usage	104	2.21	0.099	1.011
Frequency of Technology Use (Software and Online)	104	2.67	0.096	0.980
Digital Skills	104	3.59	0.084	0.866

This study evaluates the use of digital technology in mathematics teaching by 104 teachers. The results indicate significant variation in digital technology usage, with accurate average estimates. The frequency of digital technology use in middle and high school mathematics teaching also shows moderate variation. However, the average frequency estimates are highly accurate. Furthermore, mathematics teachers generally exhibit high digital skills. The average estimates of digital skills demonstrate high precision. Thus, despite variations in digital technology usage and skills among teachers, these findings provide accurate and reliable insights into patterns of technology use and digital skill levels among mathematics teachers. The observed variations explain individual differences in digital technology implementation.

Demographic relationships of teachers with digital technology usage

Table 5. Regression model fit measures

			Overall Model Test			
Model	R	R^2	F	df1	df2	p
1	0.463	0.214	2.54	10	93	0.009

The use of digital technology in mathematics teaching ($F(10, 93) = 2.54$, $p = 0.009$). The coefficient of determination ($R^2 = 0.214$) indicates that approximately 21.4% of the variability in digital technology usage can be explained by teacher demographics.

Table 6. Omnibus ANOVA test results

	Sum of Squares	df	Mean Square	F	p
Employment Status	8.758	2	4.379	4.921	0.009
Teaching Experience	9.615	2	4.807	5.403	0.006
School Level	6.060	1	6.060	6.810	0.011

The Omnibus ANOVA test results indicate that teacher demographics such as employment status, teaching experience, and school level significantly influence the use of digital technology in mathematics teaching. However, demographic factors such as age, gender, and school location do not show a significant influence on digital technology usage in mathematics teaching, as each has $p > 0.05$.

Table 7. Regression model coefficients - Digital technology usage

Predictor	Estimate	SE	t	p
Intercept [a]	2.006	0.335	5.993	< .001
Employment Status				
Government Employee with Contractual Work – Honorary Teacher	0.967	0.309	3.136	0.002
Teaching Experience				
>10 Years	-0.932	0.401	-2.323	0.022
School Level				
Junior High School – Senior High School	-0.508	0.195	-2.610	0.011

Employment status and teaching experience significantly affect the use of digital technology in mathematics teaching. Government-employed teachers with contractual agreements show a significant positive coefficient estimate ($\beta = 0.967$, $p = 0.002$), while teaching experience of more than 10 years shows a negative influence ($\beta = -0.932$, $p = 0.022$). Additionally, the middle school level also negatively correlates with digital technology use ($\beta = -0.508$, $p = 0.011$).

The Influence of Teacher Demographics on Digital Skills

Table 8. Regression model fit measures

				Overall Model Test			
Model	R	R^2	Adjusted R^2	F	df1	df2	p
1	0.464	0.215	0.131	2.55	10	92	0.009

The regression model indicates statistical significance ($F(10, 93) = 2.55$, $p = 0.009$), with 21.5% of the variability in digital skill levels explained by teacher demographics. The Adjusted R^2 of 0.131 suggests that after adjusting for the number of predictors, approximately 13.1% of the variability in digital skills can be explained.

Table 9. Omnibus ANOVA test results

	Sum of Squares	df	Mean Square	F	p
Age	4.972	3	1.657	2.543	0.061
Employment Status	7.451	2	3.725	5.715	0.005
School Level	3.511	1	3.511	5.386	0.022

Employment status (p = 0.005) and school level (p = 0.022) significantly influence digital skill levels. Age shows an influence approaching significance (p = 0.061). Gender, teaching experience, and school location do not exhibit significant influence.

Table 10. Regression model coefficients - Digital skills

Predictor	Estimate	SE	t	p
Intercept [a]	3.818	0.287	13.327	< .001
Age				
35-44 years – 25-34 years	-0.716	0.269	-2.664	0.009
45-54 years – 25-34 years	-0.506	0.421	-1.204	0.232
>54 years – 25-34 years	-0.756	0.381	-1.987	0.050
Employment Status				
Civil Servant – Honorary Teacher	0.474	0.261	1.814	0.073
Government Employee with Contractual Work – Honorary Teacher	0.893	0.264	3.381	0.001
School Level				
Junior High School – Senior High School	-0.386	0.167	-2.321	0.022

Teachers aged 35-44 years (β = -0.716, p = 0.009) and over 54 years (β = -0.756, p = 0.050) tend to have lower digital skills compared to teachers aged 25-34 years. This indicates that teachers aged 25-34 years are more adept at using digital technology compared to older teachers. Employment status also influences teachers' digital skill levels. Government-employed teachers with contractual agreements significantly exhibit higher digital skills (β = 0.893, p = 0.001) compared to contract teachers. Civil servant teachers also tend to have higher digital skills (β = 0.474, p = 0.073). Teachers teaching at the middle school level tend to have lower digital skills (β = -0.386, p = 0.022) compared to those teaching at the high school level. This difference may stem from various factors, including potentially greater technology usage demands at the high school level. Gender, teaching experience, and school location do not show a significant influence on teachers' digital skills.

Relationship between frequency of digital technology usage (software and online platforms) and digital skills, and the influence of teacher demographics

Table 11. Model fit measures

				Overall Model Test			
Model	R	R^2	Adjusted R^2	F	df1	df2	p
1	0.612	0.375	0.300	5.02	11	92	< .001

The overall regression model results. An R^2 value of 0.375 indicates that approximately 37.5% of the variability in teachers' digital skill levels can be explained by the frequency of software and online platform use, as well as teacher demographics. The Adjusted R^2 of 0.300 suggests that the model remains relevant even after adjusting for teacher demographics as predictor variables. The model is significant with an F value of 5.02 and $p < 0.001$, indicating that the model effectively explains variations in teachers' digital skill levels.

Table 12. Omnibus ANOVA test

	Sum of Squares	df	Mean Square	F	p
Frequency of Technology Use (Software and Online)	12.36	1	12.357	23.55	< .001
Teaching Experience	1.36	2	0.681	1.30	0.278
Gender	1.13	1	1.127	2.15	0.146
Age	6.51	3	2.169	4.13	0.008
Employment Status	2.54	2	1.269	2.42	0.095
School Location	2.92	1	2.916	5.56	0.021
School Level	2.09	1	2.089	3.98	0.049
Residuals	48.27	92	0.525		

Frequency of digital technology use (software and online platforms) ($p < 0.001$), age ($p = 0.008$), school location ($p = 0.021$), and school level ($p = 0.049$) significantly influence teachers' digital skills. Meanwhile, teaching experience ($p = 0.278$), gender ($p = 0.146$), and employment status ($p = 0.095$) do not show significant influence.

Table 13. Regression model coefficients - Digital skills

Predictor	Estimate	SE	t	p
Intercept [a]	2.817	0.329	8.546	< .001
Frequency of Technology Use (Software and Online)	0.394	0.081	4.853	< .001
Teaching Experience				
6-10 years – 1-5 years	-0.076	0.241	-0.318	0.751
>10 years – 1-5 years	0.307	0.310	0.989	0.325
Gender				
Female - Male	-0.248	0.169	-1.465	0.146

Predictor	Estimate	SE	t	p
Age				
35-44 years – 25-34 years	-0.807	0.241	-3.337	0.001
45-54 years – 25-34 years	-1.009	0.391	-2.579	0.012
> 54 years – 25-34 years	-1.074	0.347	-3.090	0.003
Employment Status				
Civil Servant – Honorary Teacher	0.373	0.235	1.588	0.116
Government Employee with Contractual Work – Honorary Teacher	0.530	0.248	2.137	0.035
School Location				
Rural–Urban	0.367	0.156	2.358	0.021
School Level				
Junior High School – Senior High School	-0.300	0.150	-1.995	0.049

Regression coefficients show that the frequency of digital technology use (software and online platforms) has a positive and significant impact on teachers' digital skills ($\beta = 0.394$, $p < 0.001$). Specifically for age, significant influences are observed; teachers aged 35-44 years ($\beta = -0.807$, $p = 0.001$), 45-54 years ($\beta = -1.009$, $p = 0.012$), and over 54 years ($\beta = -1.074$, $p = 0.003$) tend to have lower digital skills compared to teachers aged 25-34 years. Employment status indicates that government-employed teachers with contractual agreements have higher digital skills compared to contract teachers ($\beta = 0.530$, $p = 0.035$). School location also influences digital skills, with rural teachers having higher digital skills compared to urban teachers ($\beta = 0.367$, $p = 0.021$). School level shows that middle school teachers tend to have lower digital skills compared to high school teachers ($\beta = -0.300$, $p = 0.049$). Teaching experience and gender do not show a significant influence on teachers' digital skills.

Relationship between digital technology use, frequency of usage (software and online platforms), and digital skills

Table 14. Correlation matrix of digital technology usage, frequency, and digital skills

		Digital Technology Usage	Frequency of Technology Use (Software and Online)	Digital Skills
Digital Technology Usage	Spearman's rho	—		
Frequency of Technology Use (Software and Online)	Spearman's rho	0.620 ***	—	
Digital Skills	Spearman's rho	0.566 ***	0.456 ***	—

The correlation analysis using Spearman's rho indicates significant relationships between digital technology use, frequency of use (software and online platforms), and digital skills in mathematics teaching. The correlation coefficient between digital technology use and frequency of use (software and online platforms) based on Spearman's rho is 0.620 ($p < .001$), indicating a positive and significant relationship. The more frequently teachers use software and online platforms, the higher their digital technology usage.

Furthermore, the correlation coefficient between digital technology use and digital skills based on Spearman's rho is 0.566 ($p < .001$), indicating a significant positive relationship. Teachers who more frequently use digital technology in teaching tend to have higher digital skills. This suggests that regular use of digital technology can enhance digital skills, enabling teachers to proficiently utilize technology for both in-class and out-of-class learning activities.

Additionally, the correlation coefficient between frequency of use (software and online platforms) and digital skills based on Spearman's rho is 0.456 ($p < .001$), indicating a significant positive relationship. Teachers who more frequently use software and online platforms tend to have better digital skills.

Qualitative phase

The challenges faced by mathematics teachers in teaching mathematics in the era of digital technology and recommendations for enhancing self-management vary significantly. Respondents providing answers refer to their experiences as teachers, the location of their schools, and their habits in using technology when delivering mathematics content in class. Responses from 14 mathematics teachers were explored and analyzed.

Table 15. Challenges and recommendations for teachers

Teacher's Initials	Challenges	Teacher Recommendations
N.	Unequal availability of technology devices for students.	Regular training through Teacher Working Groups with guidance and supervision from local education authorities.
R.	Insufficient facilities and infrastructure for digital learning.	Equality in educational facilities. Government needs to directly address the conditions in rural schools.
S. F.	Lack of adequate infrastructure to support educational quality.	For digital learning programs, the government must prepare adequate facilities and infrastructure to achieve desired outcomes.
F. W.	Challenges in remote areas include a lack of internet access and learning facilities.	Mathematics teachers require specialized and more competent training to adapt to technological

Teacher's Initials	Challenges	Teacher Recommendations
		advancements.
S. D.	Absence of internet access and adequate learning facilities hindering technology integration in teaching mathematics at schools.	Government and schools need to provide internet connectivity and adequate learning facilities to support effective learning in this technological era.
H. R.	Challenges faced when teachers are not proficient with technology but are required to teach using it.	Improving management of mathematics teachers is recommended.
S. P. S.	Students' reduced focus and motivation in doing math tasks.	Organizing competitions to keep students motivated and engaged in learning.
Z. K.	Mathematics teachers need to master online learning methods or educational apps both in and out of the classroom.	Schools should provide adequate teaching and learning resources for professional development related to technology in mathematics education.
S. A.	Technological advancements change the way information is obtained and delivered; teachers need to adapt with more interactive teaching methods using digital tools like presentations, videos, and multimedia.	Not specified in the provided text.
T.	Unequal student access to technology can create learning disparities.	More frequent offline training for teachers and equipping classrooms with tools supporting effective teaching and learning like IT boards and others.
H. J.	Teaching in remote areas poses significant challenges due to insufficient facilities and infrastructure in schools amidst rapid digital technological advancements.	Maximizing Mathematics Teacher Working Groups at both district and regional levels by inviting certified speakers in their field.
M. T. B. S.	Many students have below-average basic math skills, making it difficult to implement digital technology effectively in teaching.	More regular training or similar initiatives specifically for mathematics teachers.
K. R.	Technological advancements alter the way we acquire and convey information to students.	Teachers must enhance the quality of education from various perspectives.
M.	Students easily access answers on Google or YouTube, resulting in copying answers without deeper learning.	No further recommendations provided.
H. S. S.	Drastic decline in students' willingness to learn independently, impacting their engagement in learning activities.	Hoping teachers are not burdened with excessive administrative tasks that do not align with the realities of classroom teaching, potentially affecting curriculum implementation.

This table summarizes the challenges faced by teachers in integrating technology into mathematics instruction, along with proposed recommendations to address these challenges. Based on thematic analysis results, each challenge and recommendation in this table has been organized into themes relevant to mathematics teaching in the digital era.

Table 16. Themes of challenges and recommendations for technology integration in mathematics education

Challenges			Recommendations		
Category	Code	Theme	Category	Code	Theme
Educational Facilities and Infrastructure	C1	Infrastructure and Technological Access	Professional Development	R1	Training and Professional Development
Educational Facilities and Infrastructure	C2	Infrastructure and Technological Access	Educational Facilities	R2	Educational Facilities and Infrastructure
Educational Facilities and Infrastructure	C3	Infrastructure and Technological Access	Educational Facilities	R3	Educational Facilities and Infrastructure
Internet Access and Learning Facilities	C4	Infrastructure and Technological Access	Professional Development	R4	Training and Professional Development
Internet Access and Learning Facilities	C5	Infrastructure and Technological Access	Educational Facilities	R5	Educational Facilities and Infrastructure
Technological Misunderstanding	C6	Technological Proficiency	Teacher Management	R6	Educational Management and Quality Improvement
Student Focus on Tasks	C7	Dynamics and Barriers in the Learning Process	Student Motivation	R7	Educational Management and Quality Improvement
Mastery of Online Learning	C8	Technological Proficiency	Educational Facilities	R8	Educational Facilities and Infrastructure
Technological Change	C9	Dynamics and Barriers in the Learning Process	Professional Development	R9	Training and Professional Development

Challenges			Recommendations		
Category	Code	Theme	Category	Code	Theme
Facilities and Infrastructure in Remote Areas	C10	Infrastructure and Technological Access	Professional Development	R10	Training and Professional Development
Students' Basic Mathematical Skills	C11	Dynamics and Barriers in the Learning Process	Professional Development	R11	Training and Professional Development
Improvement of Learning Quality	C12	Dynamics and Barriers in the Learning Process	Learning Quality	R12	Educational Management and Quality Improvement
Easy Access to Answers	C13	Dynamics and Barriers in the Learning Process	No Recommendations	R13	-
Students' Willingness to Learn	C14	Dynamics and Barriers in the Learning Process	Educational Administration	R14	Educational Management and Quality Improvement

Based on the thematic analysis of interviews with 14 mathematics teachers, several challenges and recommendations were identified in integrating digital technology into mathematics education. The most prominent challenges faced by the teachers were: Infrastructure and Technological Access, Technological Proficiency, and Dynamics and Barriers in the Learning Process. In response to these challenges, the mathematics teachers provided several key recommendations for policymakers at the local, provincial, and national levels. These recommendations include enhancing Educational Facilities and Infrastructure, promoting Training and Professional Development, and improving Educational Management and Quality Improvement.

Discussion

This study reveals significant relationships between teacher demographics and their use of digital technology in mathematics teaching. Teachers who are government employees with contractual agreements tend to use digital technology more intensively compared to honorary teachers. Longer teaching experience and teaching at the lower secondary school level are associated with lower digital technology use. Additionally, digital skills among mathematics teachers are influenced by demographic factors, where younger teachers exhibit better digital skills compared to their older counterparts. These findings support Perienen (2020) perspective on the importance of age in enhancing digital skills. Government employment status with contractual agreements also correlates with higher digital skills compared to honorary teachers, and the upper secondary school level shows better digital skills compared to the lower secondary school level. McCulloch et al. (2018) explain that lack of experience, professional development opportunities, and technology integration are key factors influencing digital technology adoption (de Freitas & Spangenberg, 2019; Viberg et al., 2020). Despite mathematics teachers having extensive experience with AI in classrooms, there are still concerns regarding the risk of diverting learning focus (Pörn et al., 2024). Research by Bütün (2021) shows that mathematics teachers have a positive attitude towards computer technology in mathematics education, regardless of gender or school level. Alieto et al. (2024) also conclude that there are no significant differences in technology competence between genders among teachers.

Technological advancements have transformed approaches to delivering information to learners, emphasizing that technological adaptation is more influenced by technological developments than demographic factors such as age, gender, or school location. Teacher demographics also influence leadership perceptions of online learning success. The study indicates that younger teachers, those with government employment status with contractual agreements, and those teaching at the upper secondary school level have higher digital skills. This aligns with Cahapay (2021) findings highlighting differences in teachers' beliefs about pedagogical and technological knowledge based on demographic factors (Sattayaraksa et al., 2023).

The frequency of using digital technology in mathematics teaching shows a significant positive correlation with teachers' digital skills. The more teachers use software and online platforms, the higher their digital skills. Demographic factors such as age, employment status, school location, and school level also play a role in determining these digital skills. Teachers who frequently use software and online learning platforms, are younger, have government employment status with contractual agreements, and teach at the upper secondary school level tend to have higher digital skills. Orakova et al. (2024) found that pedagogical competence and digital literacy among teachers differ significantly based on age and professional work experience. Male teachers have higher levels of technology competence and digital literacy, while female teachers in elementary schools have higher levels of pedagogical competence. These findings are also consistent with Berková et al. (2024), who concluded that online learning platform usage enhances teachers' digital skills. Teachers often use technology for lesson preparation and direct instruction (Abedi, 2023).

The findings of this study reinforce previous research on the importance of digital technology in mathematics teaching. Research by Saparbayeva et al., (2024) demonstrated that integrating design-technology activities effectively develops mathematical competencies. A Spearman's rho correlation analysis revealed a significant positive relationship between the use of digital technology, the frequency of using online learning platforms, and the level of digital skills in mathematics teaching. Teachers who frequently use online learning platforms tend to incorporate digital technology more often in their teaching and possess higher digital skills.

The use of digital technology, particularly through online learning platforms, serves not only as a teaching aid but also as a medium that enhances teachers' digital competencies. When teachers regularly engage with digital platforms, they naturally develop the skills necessary to operate the tools and features of the platforms more efficiently and effectively. Thus, a higher frequency of digital technology usage directly correlates with improved digital skills. Furthermore, Bıçak (2019) research suggests that the use of technology, such as smartboards, can enhance educational quality. The use of smartboards, as an example of digital technology in education, strengthens the delivery of content in a more interactive and accessible manner, thereby positively impacting the learning process.

In this context, the digital skills developed by teachers through the use of technology become indicators of increased teaching effectiveness. The higher a teacher’s digital skills, the better their ability to utilize technology to create a learning environment that aligns more harmoniously with students' needs. Saikkonen and Kaarakainen (2021) also emphasize the importance of digital skills in influencing the extent of technology use by teachers. They found that teachers with higher digital skills are more proactive in integrating technology into their teaching. This finding indicates that developing digital skills not only boosts teachers' confidence but also strengthens their engagement in adopting more appropriate and up-to-date technology.

Mathematics teachers in both middle and high schools, whether in urban or rural areas, expressed dissatisfaction with the technology integrated into mathematics instruction. Challenges they face include limited infrastructure, a lack of training, and low levels of technological skills among teachers. This aligns with Oni et al. (2018), who pointed out that the main barriers to integrating digital technology in schools include the lack of information and communication technology (ICT) policies, insufficient training, technical support, and hardware issues.

Researchers across various countries recommend improving technology use and teacher digital skills, such as creating supportive environments for technology adoption in schools (Stumbrienė et al., 2023), providing continuous training (Alieto et al., 2024; Fowler & Leonard, 2021; Nkundabakura et al., 2023), and integrating technology into the curriculum (Abedi et al., 2023; Orakova et al., 2024; Pappa et al., 2023).

Conclusion

Teacher demographics significantly influence the use of digital technology in mathematics education. Employment status, teaching experience, and school level are prominent domains that determine the effectiveness of teachers using technology in the classroom. Government-employed teachers with contractual agreements, those with longer teaching experience, and those teaching at the lower or upper secondary levels tend to use digital technology more frequently and have higher digital skills. Additionally, the frequency of using online learning platforms also positively correlates with teachers' digital skills. Younger teachers, those teaching in rural areas, and frequent users of online platforms demonstrate better digital skills. However, factors such as age, gender, and school location do not show significant influence in some respects. The main challenges faced by teachers in integrating technology include inadequate infrastructure, limited professional training, and insufficient technical support. Therefore, policies focusing on providing adequate technology devices, targeted and sustainable digital skills training, and improving internet access such as 4G/5G are necessary.

This study identifies an urgent need to enhance technological infrastructure in schools in Eastern Indonesia, particularly in rural areas. Concrete actions that should be taken include increasing the number of computers and laptops in schools, providing smartphones and projectors for each classroom, and improving access to 4G/5G internet. Additionally, optimizing the facilitation of digital learning platforms is essential. School policies should focus on more regular and continuous professional training, including specialized training in the use of teaching resource platforms and advanced learning management systems for mathematics software. To ensure equitable access to technology, education policies in Eastern Indonesia must give special attention to teachers and students in remote areas. Local governments must take an active and assertive role in identifying and addressing technological disparities through school digitalization policies, while also involving academics and professional teacher organizations. Further research should evaluate the effectiveness of policies implemented by regional and provincial education offices, both quantitatively and qualitatively. The focus should be on improving teachers' digital skills with TPACK components, the availability of technological infrastructure in schools, and the management of mathematics teachers in utilizing digital technology in teaching using grounded theory.

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