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Leveraging Academic Performance through Technology Utilization in Mathematics Education

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study examines the effective integration of digital tools in mathematics education to enhance students' academic performance, engagement, and problem-solving skills. It evaluates instructional strategies, identifies challenges, and proposes solutions to improve technology implementation in teaching practices.
Study Design: A mixed-method approach was employed, combining qualitative and quantitative data collection. Interviews and observations provided insights into educators' experiences, while surveys measured the frequency and effectiveness of technology usage in instruction.
Place and Duration of Study: Conducted at the University of Eastern Philippines, Laoang Campus, during the 2024–2025 academic year.

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Methodology: Six mathematics teachers were selected through purposive sampling to ensure the inclusion of educators facing challenges in integrating technology into their teaching. Data collection involved semi-structured interviews and surveys, with thematic analysis applied to qualitative data and descriptive statistics used for quantitative responses.
Results: Educators utilized diverse digital tools—including PowerPoint, GeoGebra, SPSS, HTML, Desmos, and PhotoMath to enhance lesson structure, data analysis, and interactive learning. Devices such as laptops, mobile phones, and smart TVs improved accessibility, yet challenges such as infrastructure limitations, digital literacy gaps, and student access disparities hinder full integration. Teachers addressed these barriers through strategic technology use, collaboration, and digital literacy initiatives.
Conclusion: While digital tools enhance mathematics instruction, infrastructure limitations, resource accessibility, and pedagogical constraints remain obstacles. Addressing these challenges requires sustained institutional support, improved digital infrastructure, and continuous professional development. By refining teaching strategies and fostering collaboration, educators can create inclusive and technology-driven learning environments that promote student engagement, comprehension, and academic success.

Keywords: Technology integration; mathematics education; academic performance; student engagement; problem-solving skills; mixed-method research; educational strategies; infrastructure challenges.

1. INTRODUCTION

In an era where technology permeates nearly every aspect of life, its integration into education holds immense potential to transform learning experiences and enhance academic performance. This study examines the application of technology in mathematics education, a subject often perceived as challenging by students. The incorporation of digital tools in math instruction offers numerous benefits, such as personalized learning experiences and the ability to render abstract concepts more tangible through interactive software and online platforms (Cirneanu et al., 2024). Multimedia resources further aid comprehension and retention of mathematical content. Digital tools enhance math learning for defense and security students but require support, adaptability, and solutions to overcome challenges (Cirneanu et al., 2024).

Despite the promising advantages of digital innovations, many mathematics educators encounter obstacles in effectively incorporating technology into their teaching practices. A deeper understanding of how technology facilitates student learning, improves academic outcomes, and integrates seamlessly into existing curricula is essential for maximizing its benefits (Serin & H, 2023). The rise of online learning platforms and interactive tools has significantly reshaped student engagement and information absorption. Simultaneously, contemporary education emphasizes holistic development, including social-emotional learning, critical thinking, and cultural competency, to prepare students for an increasingly dynamic world (Cirneano & Moldovueno, 2024).

International assessments such as PISA (Programme for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study) provide valuable insights into the global impact of technology on mathematics education. PISA results indicate that students who frequently use digital tools for learning mathematics tend to perform better in problem-solving tasks (OECD, 2023). TIMSS findings highlight disparities in technology access and effectiveness across different educational systems, emphasizing the need for equitable digital integration (Mullis et al., 2023). Additionally, OECD reports advocate for policies that bridge the digital divide and enhance teacher training to optimize technology-driven learning environments (OECD, 2023).

Studies indicate that integrating digital tools into math education fosters deeper student interest and engagement (Kelley et al., 2020). As educational technology evolves, mathematics instruction emerges as a particularly transformative domain. Digital resources enable educators to create dynamic, interactive learning experiences tailored to diverse learning styles and capabilities. However, challenges persist, particularly in higher education mathematics courses such as Algebra, Calculus, and Advanced Mathematics, where students often

struggle to connect theoretical knowledge with practical applications (Cirneano & Moldovueno, 2024).

Technology-driven mathematics instruction enhances students' problem-solving skills, knowledge structuring, confidence, and engagement, while also fostering interdisciplinary collaboration among educators (Reybak, 2021). While teacher candidates improve their instructional methods, their technological proficiency (TPACK) often experiences minimal growth, highlighting the need for targeted training in digital integration (Rankes et al., 2022). Bridging ICT policy gaps in education necessitates professional development programs to reshape pedagogical beliefs and promote student-centered learning (Abedi et al., 2024). Demographic factors such as gender, age, and teaching experience exhibit minimal influence on technology adoption; however, female educators tend to demonstrate higher TPACK proficiency, underscoring the increasing relevance of hands-on experience and technology democratization post-pandemic (Li et al., 2025).

Technological tools facilitate students' interaction with mathematical concepts, enhancing visualization, fostering connections between ideas, and promoting active engagement (Rashidov, 2020). Digital platforms enable students to explore complex problems, represent abstract concepts visually, and examine mathematical relationships in a more accessible and engaging manner (Schuessler, 2020). For instance, digital manipulatives allow learners to visualize geometric shapes or algebraic equations, making abstract principles more concrete and comprehensible (Cai et al., 2020). Mathematics instruction becomes more engaging when interactive software applications and simulations present concepts in visually rich and immersive ways (Cai et al., 2020). Moreover, students with a keen interest in mathematics are more likely to participate in extracurricular learning activities, such as math clubs or competitions, which further enhance their proficiency (Arthur, 2022).

Mobile learning applications provide flexible and personalized educational experiences, strengthening study habits and academic performance when effectively integrated with traditional models to mitigate distractions (Hattie et al., 2023). Applications such as GeoGebra enhance understanding through visualization and problem-solving, though concerns regarding overreliance and accessibility require attention to encourage independent thinking (Cabugwason et al., 2024; Tamam et al., 2021). Interactive tools have also proven valuable in medical education by optimizing learning outcomes and fostering engagement, necessitating ongoing collaboration to develop effective solutions (Tuma, 2021). Additionally, interactive feedback mechanisms support formative assessment by delivering precise competency data, guiding adaptive learning pathways, and emphasizing the necessity of teacher training for seamless integration (Barana et al., 2021). Meaningful classroom technology adoption hinges on institutional support, quality professional development, and educators' pedagogical beliefs (Bowman et al., 2020).

Given the persistently high rates of poor mathematics performance, researchers have investigated underlying causes, including the impact of student interest on achievement (Warren et al., 2021). When students develop enthusiasm for mathematics, they exhibit heightened engagement, participate actively, and pursue independent learning, all of which contribute to improved understanding and motivation (Arthur, 2022). Lai & Cheong (2022) advocate for a comprehensive mathematics education approach that integrates effective knowledge representations with experiential, contextual, and collaborative learning strategies. AI-powered chatbots can assist educators in monitoring student progress and providing data-driven insights to enhance student performance while supporting external accountability measures (Birenbaum, 2023).

Classroom response systems incorporating participatory feedback tools have demonstrated success in increasing student engagement and improving communication between teachers and learners (Calor et al., 2022). Kim et al. (2020) emphasize the significant implications of instructional communication in mathematics education. Although technological advancements have enabled the development of AI-powered instructors (Nobis et al., 2025), student perceptions of machine teachers, particularly for complex mathematical content, remain an area of limited understanding (Azevedo et al., 2022).

This study explores how technological tools can be effectively leveraged to enhance student academic performance in mathematics. It investigates strategies for improving learning outcomes through educational technology,

fostering student engagement and motivation, and strengthening problem-solving abilities. Moreover, the research assesses instructional methodologies for integrating technology into teaching practices and examines the relationship between technology use and mathematics achievement. By identifying effective digital approaches, the study contributes to advancing educational practices and promoting student success in mathematics. Findings from this research can guide educators in optimizing technology integration, support institutions in shaping policies for technology-driven learning environments, and modernize mathematics instruction to better align with contemporary pedagogical trends.

1.1 Research Questions

This study was guided by the following research questions, which aimed to provide acomprehensive understanding of technology integration in mathematics education by exploring the challenges and practices of mathematics teachers. The following research questions were addressed:

1. What digital tools and technologies are currently utilized by mathematics educators in their teaching practices?
2. What are the primary challenges mathematics teachers face in integrating technology into instruction?
3. What strategies and solutions have educators developed to effectively incorporate technology into mathematics instruction to improve student learning outcomes and engagement?

2. METHODOLOGY

2.1 Research Design

The study employed a mixed-method approach to examine the integration of technology in mathematics education. This method combined qualitative insights from interviews and observations with quantitative data collected through surveys. By utilizing this comprehensive framework, the research provided a holistic understanding of teachers' experiences and highlighted the potential of technology as an innovative tool in mathematics instruction.

2.2 Population and Sample

The study focused on mathematics teachers at the University of Eastern Philippines, Laoang Campus, during the academic year 2024–2025. These educators actively incorporated technology into their teaching practices. The study examined the challenges they encountered and the solutions they implemented, providing valuable insights into the impact of technology on students' academic performance. The research group included all mathematics teachers at the university who integrated technology into their instruction, while the sample consisted of six selected participants chosen through purposive sampling. These individuals were specifically selected to ensure representation of those facing difficulties in incorporating technology into their teaching methods.

2.3 Research Instrument

An interview guide and survey questionnaire were developed to investigate the role of technology in mathematics education. The interviews focused on identifying the challenges educators faced and the strategies they employed, while the survey gathered data on the specific technologies utilized in their teaching practices. To ensure validity and reliability, the research instruments underwent expert review. Specialists in mathematics education and research methodology assessed the instruments for clarity, potential bias, and effectiveness. Their feedback was incorporated to enhance accuracy and relevance.

2.4 Data Collection

Data collection was carried out through semi-structured interviews and survey questionnaires, allowing participants to share their experiences with technology in mathematics education. Each educator participated in a one-on-one interview to discuss the challenges encountered and the solutions implemented. The survey provided additional details on the digital tools used to improve learning outcomes. Before data collection, participants received an explanation of the study’s objectives, and informed consent was obtained. Responses were transcribed and analyzed using thematic analysis to derive meaningful insights and best practices.

2.5 Data Analysis

The study employed thematic analysis to examine qualitative data from interviews, alongside descriptive statistics using frequency and percentage distribution to analyze quantitative data on technology tools used in

mathematics education. Researchers transcribed and reviewed interview recordings, conducted initial coding, and identified key themes reflecting participants' experiences. These themes underwent validation through cross-checking against raw data, were refined for clarity, and were named to enhance understanding before being interpreted about the research questions.

2.6 Ethical Consideration

Ethical protocols were strictly followed throughout the study. Informed consent was obtained from all participants, who were fully briefed on the study's objectives and their rights. Data confidentiality was preserved through anonymization and secure storage, with records deleted once they were no longer needed. Measures were implemented to minimize participant distress, with support available as necessary, and cultural sensitivity was maintained in all interactions. Transparency was ensured in reporting findings, and any potential conflicts of interest were disclosed to maintain objectivity and credibility.

3. RESULTS AND DISCUSSION

3.1 Technology Tools Used by Educators in Teaching Mathematics

The survey of six mathematics educators revealed a diverse range of technology tools utilized in instruction. PowerPoint (PPT) and GeoGebra emerged as the most frequently used, with each being selected by three respondents (50.0%). SPSS (Statistical Package for the Social Sciences) and HTML were identified by two respondents (33.3%), while Excel, Projector, Desmos, Malmath, Photomath, Laptop, Mobile Phone, and Smart TV were each chosen by one respondent (16.7%).

These findings underscore the increasing reliance on digital tools to enhance mathematics education, making instruction more interactive, accessible, and engaging. PowerPoint (PPT) is widely recognized for its ability to present structured lessons that improve focus and retention (Anderson & May, 2020). GeoGebra serves as a pivotal tool in making abstract mathematical concepts more interactive through dynamic visualizations (Zulfiqar et al., 2019). SPSS enables educators to conduct statistical analyses, supporting evidence-based instructional decisions (Kim & Kim, 2021). Similarly, HTML empowers teachers to integrate web-based interactive content, fostering student engagement (Holmes et al., 2022).

Additional tools such as Excel and Desmos facilitate data visualization and exploration, while applications like Malmath and Photomath provide guided problem-solving, boosting students' confidence (Lim & Wang, 2023; Rolim & Isotani, 2020). Hardware, including laptops, mobile phones, and smart TVs, plays a crucial role in ensuring seamless access to these tools, with smart TVs particularly bridging traditional and modern teaching methodologies (Anderson & May 2020).

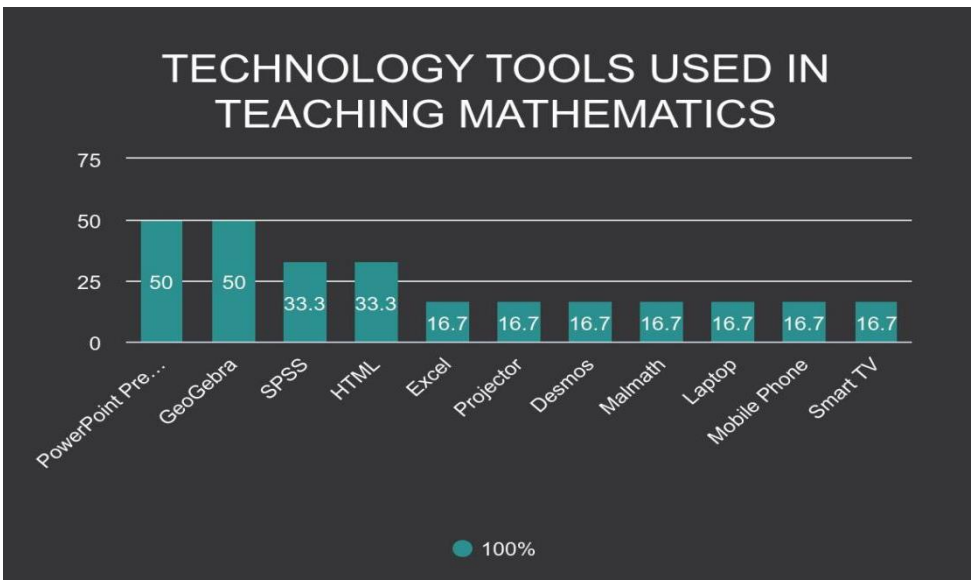

Fig. 1. Technology tools used by educators in teaching mathematics

Overall, the findings highlight educators' adaptability in integrating diverse technology tools to address various learning styles and academic needs. Effective alignment of these tools with instructional objectives can significantly enhance student engagement and academic performance (Kim et al., 2021; Holmes et al., 2022). Continuous exploration and integration of technological advancements remain essential for refining educational practices, improving learning outcomes, and fostering inclusivity in mathematics instruction.

3.2 Challenges Faced in Integrating Technology Tools in Mathematics Education

The integration of technology into mathematics instruction offers transformative opportunities but also presents significant challenges. While digital tools enhance visualization, interactivity, and data-driven decision-making, their implementation is often impeded by infrastructural limitations, technical skill gaps, student-related difficulties, pedagogical barriers, and resource constraints. Addressing these challenges requires equitable access, continuous professional development, and structured instructional strategies to maximize the benefits of technology in mathematics education.

3.2.1 Technological infrastructure limitations

The integration of digital tools into mathematics education holds the potential to revolutionize learning, making abstract concepts more tangible and interactive. However, inadequate technological infrastructure remains a major barrier, particularly for students in underserved regions. Limited access to stable internet connections, personal devices, functioning hardware, and effective technology management hinders the consistent and effective use of digital tools in classrooms. These disparities result in unequal learning experiences, restricting opportunities for students who lack technological access compared to their peers.

Here are some examples of responses that reflect this theme:

> *"Challenges that I encountered are low internet connection..."*
> *"Not all students have cellphones/gadgets."*
> *"Smart TV is not functional."*
> *"Yes, there are difficulties I encounter when using technology, but this technology is beyond my contro*l..."
>
> *"I often struggle with an unstable internet connection, which disrupts online activities."*
>
> *"Some of my students do not own laptops or mobile phones, limiting their ability to engage in digital learning."*
> *"We do not have enough computers in the classroom for every student to participate in technology-based activities."*
>
> *"Many of the computers in our school are outdated and cannot support interactive math applications."*

Studies highlight that mobile learning applications and math software significantly improve academic performance by offering personalized learning experiences and visualization tools (Hattie et al., 2023; Cabugwason et al., 2024). Viberg et al. (2020) stress the importance of adequate digital infrastructure to ensure equitable access to learning technologies. However, accessibility and technical constraints remain critical issues, as Pelayo-Dacanay et al. (2023) note that marginalized students struggle with digital participation due to technological limitations. Drijvers et al. (2024) further emphasize that overcoming these barriers is essential for effective curriculum integration and inclusive educational practices. Student engagement and interest in mathematics also play a key role in academic success. Interactive tools and online platforms enhance accessibility, encouraging participation and comprehension (Warren et al., 2021; Arthur, 2022). Enjoyment of the subject fosters additional practice through extracurricular activities, promoting deeper understanding and improved performance (Arthur, 2022).

3.2.2 Lack of technical skills and knowledge

As technology becomes more integrated into mathematics instruction, both students and teachers are expected to adapt to new digital platforms and tools. However, a significant challenge arises due to limited technical proficiency and gaps in digital literacy. Despite the potential of technology to enhance mathematical understanding, many educators and learners struggle with navigating educational software, utilizing interactive features, and configuring digital tools effectively. These difficulties impede learning progress, reduce engagement, and diminish the overall effectiveness of technology in mathematics education.

Here are some examples of responses that reflect this theme:

"One of the challenges is how I would be able to configure or set up an interactive figure..."

"It takes extra time to familiarize myself with different educational applications."
"Students often ask for additional guidance on using interactive math tools."
"I need more experience with technology to use it effectively in my lessons."
"Not knowing which function or tool in GeoGebra."
"I struggle with the design aspects of presentations."

Research indicates that technical literacy gaps hinder the effective use of digital tools. Attard and Holmes (2022) emphasize the importance of continuous professional development to equip educators with the skills needed to integrate technology effectively. Bowman et al. (2020) also highlight the necessity of teacher training focused on improving digital competence and pedagogical reasoning. Rankes et al. (2022) found that although teacher candidates refined their mathematics teaching practices, their technological proficiency remained limited, underscoring the need for direct technology training in TPACK development. Graham et al. (2021) argue that teacher training programs must include strategies to build digital competence. Viberg et al. (2020) stress the importance of social and informational support structures in successful technology implementation.

3.2.3 Student barriers and digital disparity

Digital tools play an increasingly significant role in education, particularly in mathematics instruction, where technology enhances visualization, problem-solving, and interactive learning. However, disparities in student access to technology and digital fluency present significant challenges. Many students lack personal devices, face connectivity issues, or struggle with navigating digital platforms, making technology-enhanced instruction inaccessible to certain groups. This imbalance limits the potential benefits of digital learning, disadvantaging students in an increasingly technology-driven educational landscape.

Here are some examples of responses that reflect this theme:

"Not all students can provide technology tools like a cellphone."
"I find it difficult to teach my student since they are not familiar with the software..."
"Learners from remote areas have difficulty accessing digital learning platforms."
"Students who lack technology exposure often need additional support to engage with online learning."
"Limited access to devices makes interactive lessons challenging for certain students."
"Not all students can easily understand how to manipulate mathematics tools."

Research highlights the need to address equity concerns in digital education. Engelbrecht et al. (2023c) and Circaneau et al. (2024) emphasize that while digital environments support flexible and independent learning, disparities in access disproportionately affect disadvantaged students. Devlin (2021) and Saparbayeva et al. (2024) similarly argue that technology fosters mathematical thinking and comprehension, yet learners require proper guidance and support to realize its full benefits. Bowman et al. (2020) suggest that teachers' perceptions of technology significantly influence their willingness to integrate digital tools into instruction. If educators view technology merely as supplementary rather than as transformative, its potential remains underutilized (Nobis et al., 2024).

3.2.4 Pedagogical challenges in technology integration

Despite the benefits of technology in mathematics instruction, educators face several pedagogical challenges that complicate its effective integration. While digital tools enhance interactive learning, concerns regarding time constraints, instructional balance, and student dependency on technology create barriers that teachers must address. Maintaining equilibrium between traditional and digital approaches, managing lesson preparation time, and ensuring students develop strong foundational skills remain crucial aspects of effective teaching.

Here are some examples of responses that reflect this theme:

"*It is time constraints for planning tech-integrated lessons..."*
"Students ' over-reliance on technology leads to weaker foundational skills."
"Lesson planning takes longer when incorporating interactive tools like GeoGebra and Desmos."

"I worry that students may rely on automated solutions rather than developing their reasoning skills."
"Students from remote areas may face difficulties in learning mathematics with technology due to limited internet access."

The literature highlights the importance of strategic educational planning in fostering sustainable digital learning. Adiyono et al. (2024b) stress the necessity of structured technology integration to enhance long-term digital proficiency. Malabayabas (2024) discusses the importance of balancing traditional and digital instructional strategies to sustain student engagement and improve academic performance. Guo et al. (2023b) caution that while AI tools enhance learning, they should complement rather than replace critical thinking and problem-solving. Rashidov (2020) underscores technology's role in helping students visualize abstract mathematical concepts, fostering deeper connections and interaction with the material. Schuessler (2020) reinforces this notion by emphasizing dynamic and interactive learning experiences in problem-solving and mathematical exploration. Additionally, Cai et al. (2020) note that digital manipulatives enable students to visualize geometric shapes and algebraic equations, making abstract mathematical concepts more accessible.

3.2.5 Insufficient resources and institutional support

Although educational institutions increasingly emphasize technology integration in mathematics instruction, many face limitations in resources and institutional support, preventing educators and students from fully leveraging digital tools for learning. Effective technology-enhanced instruction requires reliable digital infrastructure, comprehensive training programs for educators, student support systems, and access to modern devices. However, universities and schools—particularly those in remote or underserved areas—often lack these essential resources. Inadequate funding, outdated technological equipment, and limited administrative backing create barriers to effective digital learning, disproportionately impacting marginalized students.

Here are some examples of responses that reflect this theme:

"Universities lack technology devices."
"Students from remote areas may have limited exposure to technology."
"Limited funding makes it difficult to upgrade digital resources for both teachers and students."
"I struggle to implement interactive learning methods due to a lack of institutional support."
"Our school does not have a stable learning management system to support technology-driven education."

Findings align with existing research on institutional challenges in digital education. Nobis (2021) found that institutional profiles, such as access to computer labs and learning management systems, significantly influence technology adoption. Circaneau et al. (2024) emphasize the importance of fostering equitable digital literacy to ensure inclusive learning environments. Abedi et al. (2024) underscore the necessity of bridging the gap between ICT policy and teachers' practices through targeted education and professional development, reshaping pedagogical beliefs to enhance student-centered learning. Research also supports the notion that technology improves problem-solving, knowledge structuring, and student engagement in mathematics education, reinforcing its transformative potential (Reybak, 2021). Li et al. (2025) highlight the importance of hands-on experience and the democratization of technology post-pandemic in advancing teacher proficiency. Addressing these challenges is crucial to ensuring effective and equitable technology-enhanced learning experiences for students (Balanquit & Nobis, 2025).

3.3 Solutions Made by the Teachers in Addressing Technological Challenges

The integration of technological tools into mathematics education presents both opportunities and obstacles. While digital innovations facilitate automation, immediate feedback, and interactive learning experiences, educators must navigate challenges related to accessibility, student readiness, and effective instructional strategies. Despite these difficulties, teachers have demonstrated adaptability and ingenuity in developing solutions that enhance learning, foster digital inclusivity, and strengthen teaching methodologies.

3.3.1 Technology integration

Educators have actively embraced technology to address learning challenges in mathematics

instruction. The incorporation of GeoGebra, Desmos, AI-powered platforms, and interactive tools has transformed traditional teaching methods into dynamic, engaging, and visually enriched experiences. By strategically utilizing technology, instructors empower students to explore mathematical functions, visualize abstract concepts, and develop problem-solving skills in innovative ways.

Technology integration plays a vital role in enhancing student engagement, problem-solving abilities, and interdisciplinary collaboration among educators (Reybak, 2021; Nobis & Caparroso, 2024). Effective implementation necessitates direct technology training to improve teachers' proficiency and instructional strategies (Rankes et al., 2022). Bridging ICT policy gaps through professional development is crucial for reshaping pedagogical beliefs and fostering student-centered learning (Abedi et al., 2024). Additionally, hands-on experience is instrumental in technology adoption, with research indicating that female educators demonstrate higher proficiency, underscoring the importance of practical training (Li et al., 2025).

Here are some examples of responses that reflect this theme:

> *"Explore functions online and incorporate projector and AI technology."*
> *"Introduce tools' functions and guide proper use in mathematics lessons."*
> *"GeoGebra and Desmos help make abstract concepts more tangible for my students."*
> *"Integrating interactive platforms has improved student participation in problem-solving activities."*
> *"I dedicate time to learning advanced digital tools to enhance my teaching strategies."*

Tamam et al. (2021) highlight GeoGebra's significance in mathematics learning, as it enhances concept visualization, reasoning, and problem-solving skills. This further solidifies its role in modern education. Weigh et al. (2024) emphasize that integrating digital tools fundamentally transforms mathematics education, impacting teaching, learning, and assessment methods.

3.3.2 Adaptability and accessibility

In the pursuit of effective and equitable mathematics instruction, teachers have faced challenges in ensuring all students have access to digital learning tools. While technology integration has provided valuable opportunities for engagement, visualization, and interactive learning, not all students have had equal access to devices, stable internet connections, or familiarity with digital platforms. Recognizing these disparities, educators implemented adaptable and accessible strategies to ensure no learner was left behind due to technological limitations. By employing mixed teaching methods, alternative resource solutions, personalized learning approaches, and financial commitments, teachers proactively bridged digital accessibility gaps, fostering inclusive and effective learning environments.

Here are some examples of responses that reflect this theme:

> *"Provide printed materials with detailed problem-solving steps."*
> *"Require cellphones in college, spend personal money for resources."*
> *"Use chalkboard/whiteboard for those with limited access."*
> *"I create offline learning materials to support students without stable internet connections."*
> *"I incorporate both traditional and digital methods to accommodate different learning styles."*

This theme aligns with Pelayo-Dacanay et al. (2023), who emphasized the importance of inclusivity when integrating technology for marginalized learners. Cabugwason et al. (2024) similarly highlighted the benefits of various math applications for BSED Math students, noting that accessibility limitations must be addressed for broader adoption of educational tools. Circaneau et al. (2024) advocated for a balanced approach that combined traditional and digital methods, ensuring all students could benefit from technological advancements. Additionally, Calor et al. (2022) underscored the value of classroom response systems in promoting active participation and improving teacher-student communication in mathematics learning. By strategically incorporating these digital tools, educators created personalized, engaging, and effective learning environments tailored to students' diverse needs while fostering academic growth.

3.3.3 Teacher collaboration

As mathematics instruction increasingly incorporates digital tools and AI-driven platforms,

teachers recognize that collaboration is crucial in ensuring successful technology integration. Educators relied on knowledge-sharing, peer mentoring, and collective problem-solving to adapt digital tools to diverse learning environments, refine teaching practices, and overcome technological challenges. By working together, exchanging strategies, and providing mutual support, teachers enhanced their ability to leverage technology effectively, resulting in more engaging, interactive, and accessible mathematics instruction. Through professional learning communities, shared best practices, and cooperative lesson development, educators maximized the benefits of technology while fostering inclusivity and innovation in the classroom.

Here are some examples of responses that reflect this theme:

> *"Ask guidance from co-teachers about using specific tools."*
> *"Combine functions creatively to realize project visions."*
> *“I engage in peer mentoring to refine the integration of technology in my classroom.”*
> *“I exchange teaching strategies with fellow educators to improve digital learning methods.”*
> *“I participate in workshops and professional development programs to enhance my technological proficiency.”*

Viberg et al. (2020) highlighted shared practices and professional engagement as critical factors in successfully integrating digital tools into education. Graham et al. (2021) stressed the need for continuous professional development to support blended learning strategies effectively. Rankes et al. (2022) found that while teacher candidates improved their mathematics teaching methods, their technological proficiency showed minimal growth, emphasizing the need for structured collaboration and training programs. Reybak (2021) discussed how interdisciplinary cooperation facilitated meaningful technology implementation, improving student engagement and problem-solving abilities. Abedi et al. (2024) advocated for professional development initiatives that reshaped teachers’ pedagogical beliefs and enhanced technological integration in student-centered learning. Li et al. (2025) determined that demographic factors such as gender, age, and teaching experience had minimal impact on successful digital adoption, reinforcing the importance of hands-on experience and collaborative learning in effective technology usage.

3.3.4 Student empowerment

Teachers recognized that student empowerment was a crucial factor in maximizing the benefits of technology-enhanced mathematics learning. While digital tools such as GeoGebra, Desmos, AI-driven platforms, and interactive software provided powerful educational support, students needed confidence, skills, and a collaborative mindset to fully engage with these resources. To facilitate meaningful student empowerment, educators implemented peer learning strategies, gradual technology adoption approaches, leadership development initiatives, and inclusive digital literacy programs, ensuring students built independence, collaboration, and adaptability in a technology-driven learning environment.

Here are some examples of responses that reflect this theme:

> *"Introduce technology gradually."*
> *"Once knowledgeable, let students assist classmates."*
> *“I guide students in developing confidence when using mathematical software for problem-solving.”*
> *“I encourage independent exploration of interactive tools to enhance their learning experience.”*

These practices reflected the pedagogical shift described by Devlin (2021) and Guo et al. (2023b), who highlighted the value of promoting mathematical thinking, critical analysis, and collaborative learning through AI and technology. Empowering students to become co-constructors of knowledge enhanced both motivation and learning outcomes. Rankes et al. (2022) found that while teacher candidates improved mathematics teaching practices, direct efforts were needed to enhance their technological competency. Additionally, Reybak (2021) emphasized the interdisciplinary benefits of integrating technology into mathematics instruction, fostering collaborative learning. Integrating technology into mathematics education bridged the gap between theory and application, particularly in higher-level courses like Algebra, Calculus, and Advanced Mathematics (Cirneano & Moldovueno, 2024). Dynamic and interactive learning tools enhanced students' understanding by making abstract mathematical relationships more tangible

(Schuessler, 2020). Digital manipulatives facilitated visualization of algebraic equations and geometric structures, making complex concepts more accessible (Cai et al., 2020). Notarte et al. (2024) found that technology integration in mathematics was an effective strategy.

3.3.5 Resourcefulness

Limited institutional support posed a significant challenge to effective technology integration. Schools often lacked funding for advanced digital tools, struggled with outdated infrastructure, or failed to provide adequate resources for teachers, requiring educators to find creative ways to enhance learning despite constraints. In response, teachers demonstrated exceptional resourcefulness, adapting available tools, developing alternative teaching methods, and leveraging innovative solutions to ensure students received high-quality mathematics instruction. By repurposing existing technology, modifying instructional strategies, collaborating with peers, and utilizing free digital resources, teachers maximized learning opportunities and bridged gaps in technological accessibility.

Here are some examples of responses that reflect this theme:

> *"I borrow projectors early to ensure my lessons run smoothly."*
> *"I download lessons and videos online to supplement instruction."*
> *"I integrate low-cost technology alternatives to ensure all students have access to learning tools."*

This resourcefulness echoed findings by Nobis Jr. (2021) and Foku et al. (2023), who noted that while access to digital tools varied, effective implementation depended on teacher initiative, adaptability, and awareness of both student needs and infrastructural constraints. Hattie et al. (2023) and Cabugwason et al. (2024) emphasized that while mobile learning apps and mathematical visualization tools enhanced study habits, their effectiveness depended on proper integration into structured instructional models that minimized distractions and fostered independent problem-solving skills. Lai & Cheong (2022) advocated for a comprehensive approach that combined experiential, contextual, and collaborative learning, ensuring students developed a deeper understanding of mathematical concepts. Birenbaum (2023) and Pala et al. (2025) highlighted the role of chatbots in monitoring student progress and providing performance data to teachers, supporting both personalized instruction and external accountability. Additionally, Calor et al. (2022) and Nobis (2021) emphasized the importance of classroom response systems in encouraging active participation and strengthening communication between teachers and students. Lupas et al. (2024) explored challenges and strategies for success among future math educators.

4. CONCLUSION

The study highlights the extensive use of digital tools in mathematics education, with PowerPoint and GeoGebra widely adopted for structured lessons and interactive exploration. Technologies like SPSS, HTML, Desmos, and Photomath further enhance instruction by enabling statistical analysis, online content integration, and problem-solving guidance. Additionally, laptops, mobile phones, and smart TVs play a crucial role in increasing accessibility and engagement.

Beyond enhancing instruction, digital tools significantly impact student learning by fostering deeper conceptual understanding, improving engagement, and developing problem-solving skills. However, challenges such as inadequate technological infrastructure, digital literacy gaps, and student access disparities hinder the full potential of technology in education. Many students struggle with reliable internet access and personal devices, affecting their ability to engage with digital learning materials. Moreover, balancing traditional and technology-driven teaching methods remains a challenge for educators, requiring intentional lesson planning and pedagogical adaptation.

Despite these obstacles, educators have demonstrated resilience and innovation by incorporating interactive and AI-driven platforms to create dynamic learning environments. Peer mentoring and digital literacy initiatives help students build confidence in using technology for learning, while teachers refine instructional approaches through collaboration and shared expertise. Adaptive teaching strategies ensure that students not only utilize digital tools effectively but also develop critical thinking skills that extend beyond automated solutions.

Improving digital literacy among both educators and students is essential for fostering interactive and engaging instruction. Addressing disparities

in technology access ensures equitable learning opportunities, allowing all students to benefit from digital tools regardless of socioeconomic background. Institutional support, including funding, infrastructure upgrades, and professional development, is crucial in creating sustainable digital learning environments. Recognizing these challenges allows stakeholders to implement strategies that enhance student learning outcomes, promote accessibility, and support a more technologically advanced education system.

For successful technology integration in mathematics education, institutions must prioritize infrastructure upgrades, device accessibility, and reliable internet services. Structured professional development empowers educators and students to confidently use tools like GeoGebra, Desmos, SPSS, and HTML while fostering adaptive learning practices. A balanced approach combining traditional and digital teaching methods enriches conceptual understanding without fostering over-reliance on automation. Institutional investment, teacher collaboration, and AI-enhanced learning solutions further support problem-solving and inclusiveness in education. By overcoming technological barriers and fostering a forward-thinking digital culture, this study reinforces the need for a technology-driven, equitable learning environment that enhances student success.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

This study utilized artificial intelligence tools, including ChatGPT and Copilot, to assist in refining the manuscript. These AI-powered platforms were employed for paraphrasing content, checking grammar, improving readability, and enhancing coherence while preserving the intended meaning of the original text. The free versions of ChatGPT and Copilot were also used to streamline writing processes and ensure clarity in communication. The integration of these AI tools aimed to support academic writing while maintaining research integrity and authorial intent.

Details of the AI usage are given below:

1. Used ChatGPT and Copilot for paraphrasing paragraphs to improve the clarity and readability of the text.
2. Used ChatGPT and Copilot for checking language and grammar to enhance overall accuracy and fluency.

CONSENT

Informed consent was obtained from all participants, who were fully briefed on the study's objectives and their rights.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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