Journal of Education Method and Learning Strategy
E-ISSN 2986-9129 P-ISSN 3031-9250
Volume 3 Issue 02, May 2025, Pp. 250-262
DOI: https://doi.org/10.59653/jemls.v3i02.1587

Reflective and Technology-Integrated Pedagogy for Mathematics Teacher Education

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Received: 07-02-2025 *Reviewed: 17-03-2025* *Accepted: 09-05-2025*

Abstract

This study explores the integration of reflective pedagogy and technology-enhanced instruction in mathematics teacher education. In response to the growing complexity of 21st-century classrooms, teacher preparation programs must equip educators with the capacity for critical self-assessment and technological proficiency. This research adopts a library research approach by systematically reviewing relevant literature from scholarly journals, books, and academic reports. Through thematic analysis, five key findings were identified: (1) reflective practices promote continuous professional development, (2) technology integration increases student engagement and conceptual understanding, (3) the combination of reflection and technology strengthens teachers' technological pedagogical content knowledge (TPACK), (4) collaborative and reflective professional development enhances instructional implementation, and (5) integration challenges such as lack of confidence and pedagogical alignment require ongoing support. The study concludes that merging reflective pedagogy with technology integration creates a comprehensive framework for preparing adaptive, self-aware, and innovative mathematics educators. This integrated model provides valuable insights for the design of teacher education programs and underscores the need for professional development structures that foster both reflective and technological competencies. Future empirical research is recommended to validate these findings in classroom contexts and to assess their long-term impact on teaching outcomes.

Keywords: reflective pedagogy, technology integration, mathematics teacher education, professional development, TPACK

Introduction

Mathematics education in the digital era currently faces significant challenges in preparing competent educators capable of addressing the complex learning needs of students. Therefore, effective pedagogical approaches are essential to improving the quality of teaching. One approach that is gaining popularity is reflective pedagogy, which emphasizes the

importance of self-reflection by educators to continuously develop and adapt their teaching methods. This approach is driven by the belief that ongoing reflection helps teachers understand the challenges they face in teaching and improve their teaching practices over time (Adler, 2011; Picado et al., 2022).

On the other hand, technology-integrated pedagogy has also become an important component in mathematics education. Technology provides various tools that can enhance student engagement and support more interactive and collaborative learning approaches. The integration of technology in pedagogy allows for more dynamic teaching, accommodating various student learning styles and enriching their learning experiences (Golding & Kabuye Batiibwe, 2020).

However, despite the promising nature of both approaches, further research is needed to explore how these can be effectively combined in mathematics teacher training. The intersection of reflective pedagogy and technology integration in mathematics teacher education offers significant potential for enhancing both pedagogical and technological competencies of teachers. This study aims to explore the application of reflective pedagogy integrated with technology in mathematics teacher education and its impact on teaching quality and student engagement.

This study will provide new insights into how the combination of these two pedagogical approaches can contribute to preparing more adaptive and responsive mathematics teachers for the demands of 21st-century education.

Literature Review

Reflective Pedagogy in Mathematics Teacher Education

Reflective pedagogy emphasizes the critical role of continuous self-assessment and reflection in improving teaching practices, particularly in mathematics education. According to research, cultivating reflective habits among mathematics teachers throughout their professional training enhances their capacity to understand and address mathematical and didactic challenges effectively (Adler, 2011; Picado et al., 2022). Through multi-layered reflections, teachers can adapt their instructional methods to meet the diverse needs and experiences of students, fostering deeper engagement with mathematical content (Campbell, 2018). Furthermore, integrating reflective activities, such as reflection assignments, has been shown to boost student motivation and improve learning outcomes (Agnes et al., 2019; Reyes, 2021).

Reflective pedagogy also supports the iterative development of pedagogical strategies, allowing teachers to refine their practices based on critical analyses of their teaching experiences. This process ultimately prepares mathematics educators to navigate the complexities of diverse classroom environments and to promote student-centered learning.

Technology-Integrated Pedagogy in Mathematics Teacher Education

Technology integration in mathematics education provides innovative opportunities to enhance instructional practices and student engagement. Professional development programs that focus on the use of digital tools have significantly improved mathematics teachers' pedagogical knowledge and classroom effectiveness (Golding & Kabuye Batiibwe, 2020). Technology not only facilitates interactive and collaborative learning environments but also supports teachers' reflective practices, allowing them to analyze and refine their teaching with greater precision.

The integration of technology has proven effective in transforming mathematics instruction by enabling teachers to leverage simulations, interactive applications, and dynamic visualization tools that make abstract mathematical concepts more accessible (Reeder et al., 2009; Reichert et al., 2020). Collaborative learning models that integrate technology have also been linked to the enhancement of preservice teachers' beliefs about effective teaching and learning.

Integration of Reflective and Technology-Enhanced Pedagogy

Recent studies emphasize the synergistic benefits of combining reflective pedagogy with technology integration in mathematics teacher education. This combined approach fosters a dynamic professional development framework where teachers continuously assess and refine their instructional strategies while effectively employing technological innovations (Na & Dapat, 2023; Suh et al., 2019). Reflective practices embedded within technology-enhanced courses enable teachers to critically engage with both pedagogical theories and technological tools, promoting adaptive and responsive teaching practices.

Furthermore, reflective technology-supported practices such as digital storytelling, portfolio development, and microteaching simulations have been demonstrated to significantly enhance pre-service teachers' technological pedagogical content knowledge (TPACK), facilitating a holistic and context-responsive approach to mathematics instruction (Kafyulilo et al., 2015; Starčič et al., 2015).

In summary, the integration of reflective pedagogy and technology-enhanced learning in mathematics teacher education presents a powerful framework for developing educators who are adaptive, technologically proficient, and critically self-aware. This dual focus is essential for preparing mathematics teachers to meet the evolving demands of 21st-century classrooms.

Research Method

This study adopted a library research approach to explore the integration of reflective pedagogy and technology-enhanced teaching in mathematics teacher education. Library research is a method of collecting data and information from various credible and relevant literature sources, including books, peer-reviewed journal articles, conference proceedings, and academic reports.

The data for this study were obtained by systematically reviewing and analyzing existing literature that discusses the concepts, implementation, and outcomes of reflective pedagogy and technology integration within mathematics teacher education. Sources were selected based on their relevance, academic credibility, and recency, focusing on works published in the last 10 years.

The research process consisted of four main stages:

1. Identification – locating relevant studies using keywords such as "reflective pedagogy", "technology-integrated pedagogy", and "mathematics teacher education" across academic databases such as Google Scholar, JSTOR, ERIC, and Scopus.
2. Selection – screening literature based on inclusion criteria such as relevance to the topic, clarity of methodology, and quality of findings.
3. Analysis – critically reviewing the selected works to extract key themes, arguments, and findings related to the research topic.
4. Synthesis – organizing and interpreting the findings from various sources to develop a coherent understanding of how reflective and technology-integrated pedagogies are conceptualized and implemented in mathematics teacher education.

The results of this library research are used to identify theoretical frameworks, current trends, challenges, and best practices, which serve as the foundation for further discussion and analysis in the next sections of the paper.

To provide a clearer understanding of the logical sequence used in this study, the following conceptual diagram illustrates the structure of the research method. As this study adopts a library research approach, the diagram outlines the stages starting from literature exploration to the thematic focus areas—reflective pedagogy and technology-integrated pedagogy—within the context of mathematics teacher education. This framework helps highlight the flow of ideas and serves as a visual guide to the research process undertaken.

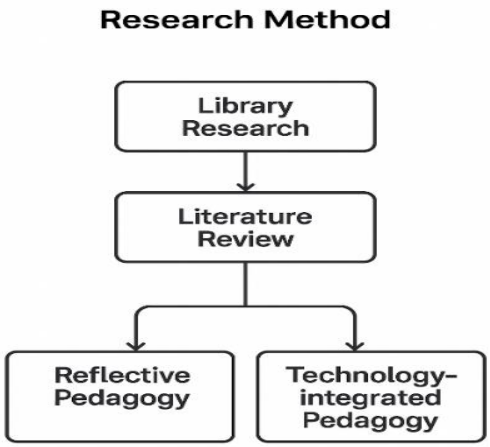

Figure 1. Conceptual Framework of the Library Research on Reflective and Technology-Integrated Pedagogy in Mathematics Teacher Education

Result

This study's findings reveal several key patterns regarding the integration of reflective pedagogy and technology-enhanced teaching in mathematics teacher education:

Reflective Pedagogy Enhances Professional Growth

The literature consistently shows that engaging pre-service and in-service mathematics teachers in reflective activities—such as reflective journaling, portfolio development, and structured self-assessment—plays a critical role in shaping high-quality, adaptive educators. These reflective processes support the development of critical thinking skills, enhance teachers' self-awareness regarding their professional strengths and areas for improvement, and significantly improve pedagogical decision-making in diverse classroom contexts (Adler, 2011; Campbell, 2018; Picado et al., 2022). Reflective journaling allows teachers to document, examine, and revise their thoughts on instructional practices; portfolio development enables them to collect and analyze evidence of growth over time; and structured self-assessment encourages systematic evaluation of teaching effectiveness. Together, these practices provide opportunities for ongoing professional inquiry and facilitate a deeper engagement with the pedagogical process. In mathematics education specifically, where abstract reasoning and problem-solving are central, the ability to reflect critically on one's teaching strategies is essential for fostering student understanding and engagement. As reflective competence develops, teachers become more responsive to students' cognitive and emotional needs, positioning them to address misconceptions and adjust instructional techniques with greater precision and confidence.

Reflective practices enable teachers to adapt their instructional approaches to the diverse and evolving needs of students and to develop a deeper, more nuanced understanding of mathematical concepts, pedagogy, and learning theory. These practices support a learner-centered mindset, allowing educators to evaluate how their teaching impacts different types of learners and to make thoughtful adjustments that promote inclusion, equity, and academic success. In mathematics education, where learners often struggle with abstract symbols, procedures, and logical reasoning, the ability to reflect on how content is delivered is vital. Teachers who engage in reflection can identify gaps in students' conceptual understanding, select more appropriate representations, and employ multiple strategies to clarify difficult topics. Additionally, reflective practice fosters professional resilience by encouraging teachers to see teaching as a dynamic, evolving process rather than a fixed set of routines. This mindset helps teachers remain open to feedback, innovation, and change, especially in the face of challenges such as curriculum reform, technological integration, or diverse classroom populations. Ultimately, cultivating reflective habits positions mathematics teachers to become more effective facilitators of learning and lifelong learners themselves, continually striving to refine their practice in response to evidence and student needs.

Technology-Integrated Pedagogy Improves Student Engagement

Studies demonstrate that integrating technology tools—such as dynamic simulations, interactive software, and collaborative online platforms—creates significantly more engaging and effective mathematics learning environments (Golding & Kabuye Batiibwe, 2020; Reeder

et al., 2009; Reichert et al., 2020). These tools allow students to interact with mathematical ideas in real time, manipulate variables, and receive immediate feedback, which supports deeper conceptual understanding. Technology use in the classroom encourages active learning by transforming students from passive recipients of information into active problem-solvers and decision-makers. It also facilitates more accurate and intuitive visualization of complex and abstract mathematical concepts, such as functions, geometric transformations, and statistical variability. Furthermore, technology supports differentiated instruction, allowing educators to tailor content to diverse student needs, abilities, and learning preferences. Collaborative digital platforms, such as shared whiteboards or online discussion forums, promote cooperative learning and peer-to-peer engagement, which have been linked to improved academic performance and motivation. Additionally, the use of technology cultivates essential 21st-century skills, including digital literacy, critical thinking, and communication, which are increasingly relevant in modern education. When used thoughtfully, technology becomes not just a delivery tool but a catalyst for deeper cognitive engagement, creativity, and meaningful mathematical discourse among students.

Combination of Reflection and Technology Strengthens Teaching Competencies

When reflective pedagogy is embedded within technology-rich environments, mathematics teachers exhibit enhanced technological pedagogical content knowledge (TPACK), which is essential for designing and implementing effective instruction in the 21st century (Kafyulilo et al., 2015; Na & Dapat, 2023; Starčič et al., 2015; Suh et al., 2019). The combination of structured reflection and digital tool usage encourages teachers to think critically about the alignment between content, pedagogy, and technology. Reflective analysis enables them to evaluate the impact of various technological tools on student engagement, conceptual understanding, and problem-solving abilities. Moreover, teachers become more capable of identifying the affordances and limitations of specific technologies in relation to their instructional goals. This process not only strengthens their confidence in using digital resources but also cultivates an adaptive mindset that is responsive to students' learning needs and classroom challenges. By consistently engaging in structured reflection—such as reviewing digital lesson recordings, assessing student feedback, or analyzing performance data—teachers can refine and personalize their teaching approaches. This leads to more effective and inclusive instruction, fostering both academic growth and technological fluency among learners. Ultimately, embedding reflective pedagogy in technology-integrated teaching fosters a professional culture of continuous improvement and innovation in mathematics education.

Collaborative and Reflective Professional Development is Essential

Professional development models that combine reflective activities and technology training significantly contribute to teachers' readiness and confidence in implementing innovative and student-centered teaching practices. These integrated programs are designed not only to build technical skills but also to cultivate a reflective mindset that encourages teachers to question, adapt, and improve their instructional methods. Programs that emphasize collaborative reflection, peer feedback, and iterative redesign of technology-integrated lessons have been shown to be particularly effective in promoting lasting pedagogical transformation

(Choi & Sunwoo, 2024; Golding & Kabuye Batiibwe, 2020; Kersaint, n.d.). Through collaborative reflection, teachers engage in shared inquiry that fosters professional dialogue, co-construction of knowledge, and critical examination of instructional strategies. Peer feedback offers diverse perspectives that challenge assumptions and spark new ideas, while iterative lesson redesign provides structured opportunities to refine digital instructional tools based on reflective evaluation and real-world classroom application. These processes not only improve technological pedagogical content knowledge (TPACK), but also foster a growth-oriented professional culture where innovation, adaptability, and student engagement become central priorities. Furthermore, when such development is sustained over time and supported by institutional infrastructure, teachers are more likely to integrate technology meaningfully, rather than superficially, into their mathematics instruction.

Challenges in Integrating Technology and Reflection

Despite the benefits, the literature highlights several persistent challenges that hinder the effective integration of technology in mathematics education. Among the most common obstacles are teachers' initial technological anxiety, lack of confidence in using digital tools, and difficulties in aligning technology use with specific pedagogical goals and learning outcomes (Hughes et al., 2020; Suh et al., 2019). These challenges are particularly evident among teachers with limited prior experience or inadequate training in educational technology. In such cases, the introduction of new tools can feel overwhelming and disconnected from established instructional practices, leading to resistance or superficial adoption. To address these issues, continuous reflective practice is essential, as it encourages teachers to confront their limitations, examine their assumptions, and gradually build confidence through experience and feedback. Supportive professional development environments—characterized by mentorship, peer collaboration, and hands-on workshops—play a critical role in fostering these reflective habits. Such environments provide safe spaces for experimentation, encourage open dialogue about challenges, and promote iterative learning. Over time, this reflective and supportive process helps teachers shift from technology as a novelty to technology as a purposeful, integrated component of effective pedagogy, ultimately enabling them to design richer, more student-centered mathematics learning experiences.

Summary of Findings

Reflective pedagogy and technology integration, when combined, provide a comprehensive framework for improving mathematics teacher education by fostering critical thinking, technological proficiency, and adaptive teaching practices. However, successful implementation requires ongoing professional support and a reflective mindset to address integration challenges effectively.

To provide a clearer overview of the key findings derived from the literature review, a summary table is presented below. This table highlights the main results related to the integration of reflective pedagogy and technology-enhanced instruction in mathematics teacher education, along with brief descriptions and supporting references. The summarized findings aim to illustrate the patterns and trends identified across multiple studies and support the development of a comprehensive understanding of the research topic.

Table 1. Summary of Findings.

No.	Finding	Description	Supporting Literature
1	Reflective pedagogy enhances teacher professional development	Reflective practices (journals, self-assessment) help teachers critically evaluate their methods and adapt instruction to students' needs.	Picado et al., 2022; Adler, 2011; Campbell, 2018
2	Technology integration promotes student engagement	Use of simulations, interactive tools, and digital platforms improves learning motivation, visualization, and collaboration.	Golding & Batiibwe, 2020; Reeder et al., 2009; Reichert et al., 2020
3	Combined approach improves TPACK and instructional innovation	Reflective use of digital tools enhances teachers' ability to integrate content, pedagogy, and technology effectively.	Na & Dapat, 2023; Suh et al., 2019; Starčič et al., 2015; Kafyulilo et al., 2015
4	Collaborative, reflective professional development boosts implementation	Training models that include reflection and teamwork help teachers internalize and apply technology-enhanced pedagogy more effectively.	Golding & Batiibwe, 2020; Choi & Sunwoo, 2024; Kersaint, n.d.
5	Teachers face initial challenges with technology integration	Barriers include low confidence, anxiety, and lack of alignment between tools and pedagogical goals—requiring reflective scaffolding and mentorship.	Suh et al., 2019; Hughes et al., 2020

Discussion

The findings of this study underscore the critical role of integrating reflective pedagogy with technology-enhanced instruction in mathematics teacher education. In an educational landscape that increasingly demands adaptability, innovation, and student-centered approaches, reflective practices serve as a foundational element for the continuous professional growth of mathematics teachers. These practices allow educators not only to examine their instructional techniques but also to make informed pedagogical decisions based on evidence, student feedback, and evolving classroom dynamics. By engaging in reflective journaling, portfolio development, and structured self-assessment, teachers are able to critically analyze their teaching strategies, uncover implicit biases, and evaluate the effectiveness of their methods in promoting conceptual understanding (Adler, 2011; Campbell, 2018; Picado et al., 2022). Reflection fosters a culture of inquiry, in which teachers become active participants in their own learning process, enabling them to adapt to students' diverse cognitive, social, and cultural backgrounds. In mathematics education, where abstract reasoning and problem-

solving are central, reflective competence empowers educators to recognize and respond to misconceptions, personalize instruction, and deepen their own understanding of mathematical thinking. This iterative process transforms teaching from a static routine into a dynamic and evolving professional practice that aligns with the complexities of 21st-century classrooms.

The incorporation of technology into mathematics pedagogy has further amplified the impact of reflective practices, offering powerful tools that enhance instructional design and student learning experiences. Tools such as dynamic simulations, interactive applications, and collaborative digital platforms have been widely recognized for their ability to promote active student engagement and facilitate deeper conceptual understanding of mathematical ideas (Golding & Kabuye Batiibwe, 2020; Reeder et al., 2009; Reichert et al., 2020). hese technologies enable learners to explore mathematical relationships visually and interactively, supporting the development of critical thinking and problem-solving skills. Through strategic integration, teachers can make abstract and complex concepts—such as calculus, geometry, or statistical modeling—more accessible and intuitive. Additionally, these tools encourage student participation through features such as real-time feedback, multiple representations, and digital manipulatives. The use of collaborative platforms also fosters peer-to-peer interaction, allowing students to co-construct knowledge and engage in meaningful discourse. For educators, technology offers the flexibility to differentiate instruction by providing varied levels of support, pacing, and representations tailored to students' individual needs. This personalized approach enhances equity and inclusion within the mathematics classroom. When combined with ongoing reflective practice, technology becomes not just a supplement but an integral component of effective, responsive, and innovative teaching.

The synthesis of reflective pedagogy and technology-enhanced learning plays a pivotal role in supporting the development of technological pedagogical content knowledge (TPACK) among mathematics teachers. TPACK is essential for designing learning experiences that integrate content expertise, effective pedagogy, and relevant technology tools in a coherent and purposeful manner. Structured reflection on the use of technology in the classroom enables educators to critically evaluate the effectiveness of digital tools not only in terms of usability but also in terms of their pedagogical value and alignment with learning objectives (Kafyulilo et al., 2015; Na & Dapat, 2023; Starčič et al., 2015; Suh et al., 2019). Through reflective analysis, teachers are encouraged to reconsider their instructional goals, refine content delivery strategies, and experiment with innovative approaches that better meet the diverse needs of students. This continuous process of feedback, evaluation, and redesign transforms technology from a passive aid into an active agent for pedagogical change. This finding aligns closely with Kersaint's (n.d.) observation that deliberate reflection, when paired with targeted technological integration, fosters purposeful and meaningful pedagogical adaptations. Moreover, teachers who regularly engage in this reflective cycle are more likely to become adaptive experts—capable of navigating rapid technological changes and reimagining mathematics instruction in ways that are engaging, effective, and student-centered.

Moreover, professional development programs that foster collaborative reflection and iterative technology design practices are essential to sustaining the pedagogical and technological gains achieved through initial training. These programs create a structured environment where

teachers can engage in ongoing dialogue, share classroom experiences, and co-construct knowledge through mutual support and feedback. When teachers collaborate to design, implement, and refine technology-integrated lessons, they not only enhance their digital competencies but also deepen their understanding of pedagogical strategies that are responsive to student needs. Such collaborative efforts also help mitigate isolation often experienced in teaching, building professional learning communities that prioritize growth and innovation. These programs not only improve technical proficiency but also cultivate a reflective mindset that is crucial for continuous professional improvement, adaptability, and instructional resilience (Choi & Sunwoo, 2024; Golding & Kabuye Batiibwe, 2020). Teachers become more willing to experiment, analyze failures constructively, and reframe challenges as opportunities for learning. These findings reinforce previous studies that emphasize the importance of embedding reflective practices within technology training, ensuring that professional development is not a one-time event but a sustained process that facilitates meaningful, context-driven instructional change. In this way, teachers are empowered to take ownership of their development and continuously enhance their effectiveness in mathematics education.

Nevertheless, several challenges persist despite the growing emphasis on reflective and technology-integrated pedagogy. Many teachers, particularly those with limited prior exposure to educational technology, often experience initial anxiety and apprehension when expected to incorporate digital tools into their instruction. This anxiety is frequently compounded by a lack of confidence in their own technological abilities and uncertainty about how to effectively align these tools with pedagogical objectives and curricular standards (Hughes et al., 2020; Suh et al., 2019). As a result, some educators may either avoid using technology altogether or adopt it superficially without meaningful instructional integration. Addressing these challenges requires the establishment of supportive professional learning communities that foster psychological safety and encourage experimentation. Within these communities, teachers should be given space to take risks, share their successes and failures, and receive constructive, ongoing feedback. Peer collaboration and mentoring can also play a critical role in building confidence and modeling best practices. Moreover, embedding a strong culture of reflective practice within these communities allows teachers to continuously assess and refine their instructional approaches, turning obstacles into opportunities for growth. By normalizing learning through trial and reflection, such environments help educators gradually develop the skills, mindset, and resilience needed to navigate the evolving demands of technology-rich mathematics classrooms.

In summary, integrating reflective pedagogy and technology-enhanced instruction offers a powerful framework for preparing adaptive, technologically proficient, and reflective mathematics teachers. Future initiatives should focus on designing professional development programs that systematically incorporate reflection within technology training to maximize the potential of both approaches.

To further elaborate on the key discussion points derived from the findings, a summary table is presented below. This table connects the major themes identified in the study with relevant theoretical frameworks and prior research. By organizing the discussion in this format, the relationships between reflective pedagogy, technology integration, and mathematics teacher

education become more explicit and structured, offering a clearer synthesis of how the literature supports the study's conclusions.

Table 2. Summary of Discussion

No.	Theme	Discussion Point	Supporting Literature
1	Reflective practice as a foundation for growth	Reflective activities strengthen teachers' critical thinking and adaptability, aligning with best practices in mathematics education.	Picado et al., 2022; Adler, 2011; Campbell, 2018
2	Technology as a tool for engagement	Integration of digital tools facilitates interactive learning, making abstract mathematical concepts more accessible to students.	Golding & Batiibwe, 2020; Reeder et al., 2009; Reichert et al., 2020
3	Strengthening TPACK through reflection	Reflection on technology use enhances teachers' TPACK development, ensuring purposeful integration of digital resources into instruction.	Na & Dapat, 2023; Suh et al., 2019; Starčič et al., 2015; Kafyulilo et al., 2015
4	Importance of collaborative professional development	Professional learning communities that emphasize reflection and collaboration promote sustained adoption of technology-enhanced pedagogy.	Choi & Sunwoo, 2024; Golding & Batiibwe, 2020; Kersaint, n.d.
5	Addressing integration challenges	Overcoming initial resistance to technology requires reflective support systems, mentoring, and iterative practice to build teacher confidence and competency.	Suh et al., 2019; Hughes et al., 2020

Conclusion

This study concludes that the integration of reflective pedagogy and technology-enhanced instruction offers a robust and synergistic framework for advancing mathematics teacher education. Reflective practices support teachers' professional growth by promoting critical thinking, self-awareness, and instructional adaptability. At the same time, the use of technology enriches pedagogical approaches by fostering engagement, collaboration, and conceptual understanding among students.

When combined, these two approaches significantly enhance teachers' technological pedagogical content knowledge (TPACK), enabling them to design and deliver more effective and context-responsive instruction. However, the successful implementation of this integrated model requires continuous support through well-structured professional development programs that include collaborative reflection and sustained practice with digital tools.

Limitations of this study include its reliance on secondary data through library research, which may not fully capture practical classroom dynamics. Therefore, future research should include empirical classroom-based studies to validate and expand upon the findings presented here. Additionally, investigations into the long-term impact of reflective technology-integrated pedagogy on teacher performance and student learning outcomes are recommended.

Ultimately, cultivating reflective and technologically proficient mathematics educators is essential for preparing students to thrive in a rapidly evolving educational landscape.

Declaration of conflicting interest

The authors declare that there is no conflict of interest in this work. The author have contributed equally and have no financial, professional, or personal relationships that could have appeared to influence the content or conclusions of this article

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