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Technology-Enhanced Learning (TEL): How Does It Affect Pre-Service Mathematics Teachers?

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ABSTRACT

The rapid advancement of ICT has fundamentally reshaped the educational landscape, creating a critical need for educators to be proficient in technology integration. This study investigates the influence of Technology-Enhanced Learning on the professional development of pre-service mathematics teachers, focusing on its impact on their teaching competencies and overall readiness. This research employs a systematic literature review, adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Twenty-six relevant articles published between 2017 and 2025 were identified from six academic databases for in-depth analysis. The findings were categorised into cognitive, affective, and psychomotor domains. The results reveal that TEL significantly enhances PMTs' cognitive abilities, such as conceptual understanding, problem-solving, and reasoning skills, while also improving motivation, self-efficacy, and confidence in the affective domain. In the psychomotor domain, it develops essential technical competencies, creativity, and readiness for technology-based teaching. In conclusion, integrating TEL is pivotal for modern teacher education programs. It not only equips future mathematics teachers with the necessary 21st-century skills but also fosters a positive disposition towards technology in the classroom. Future research should conduct empirical studies to explore the pedagogical potential of emerging technologies for strengthening digital literacy, creativity, and pedagogical innovation among pre-service mathematics teachers.

Keyword: Mathematics Education; Pre-Service Teachers; Technology-Enhanced Learning

INTRODUCTION

The rapid advancement of ICT in the last ten years has greatly impacted the education sector. The integration of technology into education has fundamentally transformed teaching and learning, providing new opportunities to enhance educational experiences. A study by Rodríguez-Jiménez et al. (2023) also explained that the use of technology in mathematics learning can enhance performance, motivation, and problem-solving ability. Technological advancements can change teachers' roles from solely curriculum designers to facilitators who use appropriate technology to deliver educational information (Kereluik & Mishra, 2011). This transformation inherently presents a new challenge: the need for teachers to develop an understanding of technology while optimising its use to create an effective learning process. This integration aligns with the TPACK framework, which emphasises the interconnection of technological, pedagogical, and content knowledge as essential components of effective technology-based instruction (Mishra & Koehler, 2006).

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Teacher training for the effective use of technology in education appears to be a crucial element in nearly all educational enhancement initiatives and educational restructuring schemes (National Council for Accreditation of Teacher Education, 1997). PSTs must have a deep understanding of relevant mathematics to improve their teaching skills. Studies by Ottenbreit-Leftwich et al. (2010) indicate that exposing future teachers to technology can improve their abilities and capabilities and effectively change their attitudes towards incorporating technology. Therefore, equipping prospective teachers with conceptual understanding and technical skills in technology is essential to improve their competence and foster a positive attitude towards learning innovation.

However, most prior research has focused more on the use of technology in classroom learning. A study by Cevikbas & Kaiser (2023), examined whether the flipped classroom model positively impacts mathematics learning. However, the article discusses the implementation of the flipped classroom approach only in general mathematics contexts, particularly during the pandemic, without providing an in-depth analysis of how technology integration might enhance future teachers' competencies. Another literature review by Dockendorff & Zaccarelli, (2025) focuses on the preparation of pre-service mathematics teachers; however, it is limited to secondary education. There has been no comprehensive synthesis that holistically maps the impact of TEL on prospective mathematics teachers. In particular, the understanding of how TEL simultaneously affects their domains of professional development, both cognitive, affective, and psychomotor, is still fragmented and requires systematic review. The objective of this research is to systematically investigate the influence of TEL on prospective mathematics teachers, with particular emphasis on how TEL contributes to the development of their teaching competence and overall professional readiness across the cognitive, affective, and psychomotor domains. Additionally, this study aims to identify the specific types of technologies commonly used in the literature and analyse how these technologies support the enhancement of competencies among pre-service mathematics teachers.

METHOD

This article followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines developed by Moher et al. (2009). These databases were selected for their high indexing standards and broad coverage of high-quality publications in education and educational technology. The detailed search queries used in each database are presented in Table 1.

Table 1. Search Terms Articles

Scopus	TITLE-ABS-KEY ("technology-enhanced learning" OR "TEL" OR "digital learning" OR "technology integration") AND TITLE-ABS-KEY ("pre-service mathematics teachers" OR "pre-service math teachers" OR "pre-service teachers" AND "mathematics")
Eric	("technology enhanced learning" OR "digital learning" OR "educational technology") AND ("pre-service mathematics teachers" OR "preservice math teachers" OR "mathematics teacher education")
Proquest	("technology-enhanced learning" OR "digital learning" OR "technology in education") AND ("pre-service mathematics teachers" OR "preservice math teachers")
Emerald	("technology-enhanced learning" OR "digital education" OR "ICT in

Insight	education") AND ("pre-service mathematics teachers" OR "teacher trainees in mathematics")
Taylor and Francis	("technology-enhanced learning" OR "TEL" OR "digital pedagogy") AND ("pre-service mathematics teachers" OR "pre-service math teachers")
Springer	("technology integration" OR "educational technology" OR "digital tools") AND ("conceptual understanding") AND ("pre-service mathematics teachers" OR "prospective teachers") AND ("mathematics education")

The specific inclusion and exclusion criteria used to determine article eligibility are detailed in Table 2, while the flowchart illustrating the article selection process is provided in Figure 1.

Table 2. Article Selection Criteria

Inclusion criteria (IC)	Exclusion criteria (EC)
IC1 Studies at all levels of mathematics education	EC1 Studies in disciplines other than mathematics education
The IC2 Study focuses on the use of technology in mathematics learning	EC2 Technology is mentioned in the study, but the focus is not on pre-service teachers.
IC3 The study reports the results of the study on the impact of technology use on pre-service teachers.	EC3 Editorials, books, book chapters, conference papers
IC4 Peer-reviewed article	EC4 Languages spoken other than English
IC5 Articles in English	EC5 Articles in the form of systematic literature review, meta-analysis, and bibliometric analysis
IC6 Articles published in the 2017–2025 time frame	EC6 Articles are indexed in databases other than the one defined.
IC7 Articles indexed in the databases of Scopus, Taylor & Francis, ProQuest, Emerald, Eric and Springer	EC7 Use of technology unrelated to pre-service teacher skills

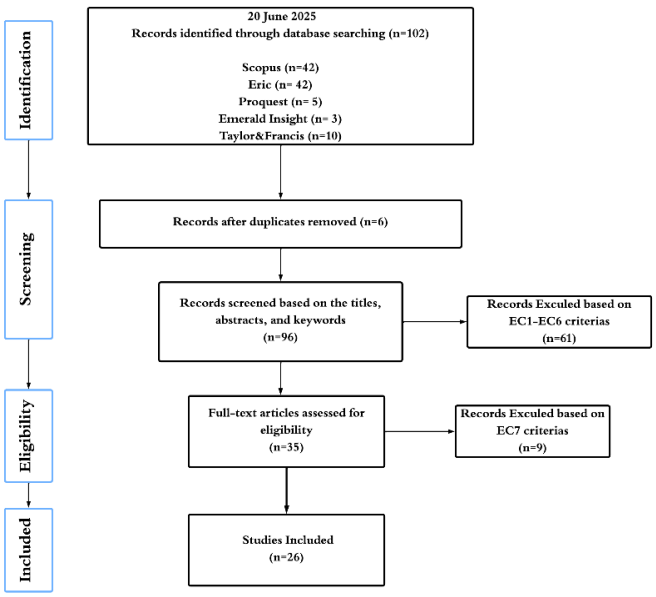

Figure 1. Flow chart of the article's selection process

RESULTS AND DISCUSSION

Results

The systematic literature review includes 26 articles that meet the inclusion criteria and have undergone a thorough evaluation for further analysis. The study's results are presented in detail in Table 3 (Appendix). The extraction result data is processed and analysed to synthesise the impact of TEL on mathematics learning outcomes of PMTs across cognitive, affective, and psychomotor aspects. Table 4 presents the findings of the synthesis of TEL for PMTs.

Table 3. Results of the synthesis of TEL for PMTs

Aspects	Variables	Number of Researches
Cognitive	Logical Thinking Skill	1
	Understanding concept	5
	Reasoning Ability	1
	Problem-Solving Skill	2
	Connection Skill	1
Affective	Self-efficacy	4
	Positive Attitude	8
	Interest	2
	Self-belief	1
	Motivation	3
	Commitment	1
	Self-confidence	1
Psychomotor	Technical Skill (Digital Skill)	5
	Teaching Skill	3

Discussion

Support for Diverse Teaching Methods by Enhancing Visualisation for A Better Cognitive Ability

Technology, such as computers and online resources, offers invaluable support for visual learners by providing visual representations that are often impossible to create with traditional pen-and-paper methods. Technology enables the manipulation of mathematical objects, thereby boosting the teaching of geometry through activities such as angle designing and shape manipulation. By employing it selectively, pre-service teachers can highlight the advantages of technology in achieving academic goals and enhancing teaching effectiveness, compared to traditional methods. Such activities will enhance pre-service teacher understanding of various mathematical concepts. For example, tools such as dynamic geometry software may help students observe geometric details, investigate connections, and develop logical thinking skills for geometric proofs. A study by Aytekin & Kiymaz, (2019) reported that visualisation of linear algebra and geometry concepts through GeoGebra helps pre-service teachers understand concepts more deeply than just memorising definitions. They become able to visualise the concept, making their understanding clearer and less abstract. Patkin & Plaksin (2019) also reported that the use of GeoGebra in geometry materials allows

pre-service teachers to change the parameters of geometric figures in real time and see their effects from various perspectives. This approach reinforces a visual understanding of spatial relationships and geometric properties, which is difficult to achieve through traditional static methods. In addition to better understanding, the integration of digital education technology has a positive effect and is considered effective by most prospective mathematics teachers in developing their logical thinking skills. The evidence indicates that the use of technology in mathematics learning greatly supports the improvement of prospective teachers' competence in logical thinking and problem-solving.

The use of technology by pre-service teachers in mathematical learning, especially to improve the visualisation of abstract concepts, has a significant impact on their cognitive load. The application of appropriate, pedagogically integrated technology enables pre-service teachers to create active, exploratory, and participatory learning experiences. These strategies can reduce their cognitive load compared to traditional passive learning approaches, both during their learning process and in teaching students later in life. (Sweller, 1988). On the contrary, the inappropriate or excessive use of technology can actually increase the cognitive load. When technology is not used strategically to support conceptual understanding, pre-service teachers may have difficulty organising information, prioritising their focus, or establishing meaningful connections essential to the learning process. These issues can lead to low learning effectiveness and a suboptimal understanding of the mathematical concepts taught.

The Development of Pre-Service Mathematics Teachers (PMTs) Digital Skills and Improvements of the Affective Aspect

Being exposed to technology enables pre-service teacher to develop significant digital skills essential in the modern workforce while enhancing their proficiency and adaptability to technological advances. Pre-service teacher also enhances their digital self-efficacy and digital citizenship, acquiring the skills and knowledge required to integrate technology into their teaching methods successfully. Integrating technology into teaching practices reduces anxiety and enhances pre-service teachers' confidence in using digital tools, thereby promoting a collaborative learning environment. Furthermore, pre-service teachers have reported increased confidence and decreased anxiety when integrating technology into their mathematics classes following technology training workshops.

Based on Self-Determination Theory (SDT), the use of technology in learning can affect a person's motivation level depending on the extent to which it supports or hinders the fulfilment of three basic psychological needs: competence, autonomy, and relatedness. Appropriately designed and implemented technology in learning contexts can strengthen pre-service teachers' sense of competence by providing appropriate challenges, constructive feedback, and opportunities to master concepts in greater depth. In addition, when technology provides flexibility in accessing and organising learning according to individual preferences, it supports autonomy, i.e., the feeling of control over one's learning process. On the other hand, technology can also strengthen connectedness through collaborative features, online communication, and social interaction, enabling pre-service teachers to engage in a mutually supportive learning community. However, if technology is used rigidly and unresponsively, it can hinder the fulfilment of these psychological needs, which ultimately negatively impacts intrinsic motivation and engagement in learning. This is in line with the results of the study by Bruna, (2025), which found that integrating digital technology into teacher training programs can increase the motivation and involvement of pre-service teachers and potentially improve

the quality of mathematics teaching they provide in the future. The use of technology during the training period is believed to foster greater motivation and active engagement, which positively impacts the quality of pre-service teachers' teaching after they become teachers. With positive experience and technology integration skills, they are better equipped to provide interactive, innovative, and appropriate math instruction to meet the needs of modern students.

Integrating Technology into Curriculum and Instructional Strategies to Improve Teaching Effectiveness and Efficiency

The accessibility of resources, technical assistance, and an ideal environment significantly affect the simplicity of integrating technology in education. Appropriate supporting environments are crucial for the successful integration of technology. Furthermore, technology can be applied to enhance curriculum delivery and instructional strategies, making learning more effective and efficient. It enables the integration of various instructional approaches that fit various learning styles and preferences. Additionally, it may be used as an educational instrument to develop a deep understanding through advanced cognitive activities, such as project-based tasks, problem-solving, and decision-making. Technology, such as Web 2.0 tools, enhances teaching performance, productivity, and effectiveness by improving the learning process—for instance, a study by Ü. Kul et al. (2018) reported that preservice teachers' attitudes have shifted towards more positive views of the use of Web 2.0 in mathematics learning, moving away from a traditional tendency towards a more passive use of technology. They show a strong intention to use Web 2.0 tools in a planned manner in their future learning process, including across a variety of mathematics topics, not just in geometry materials as before. The use of technology such as GeoGebra helps them visualise abstract fraction concepts more concretely and interactively, which is expected to improve students' understanding.

Supportive of Modern Educational Needs

Technology facilitates the incorporation of diverse teaching approaches by offering interactive, engaging methods that align with current educational standards and expectations. It helps teachers implement strategies that enhance students' comprehension of complex concepts and accommodate diverse learning needs, enabling students to explore, produce, and engage with educational resources to foster a more dynamic learning environment. In an era of rapid technological development, students must acquire proficiency in technology to prepare for their future professional endeavours. A study by Kreis et al., (2024) reports that integrating technology, such as a flipped classroom, has a significant impact on future learning. The integration of technology in the flipped classroom model has improved the academic performance and confidence of preservice teachers in mathematics while preparing them to face the challenges of modern education. This aligns with the findings of the study. Karjanto & Acelajado, (2022) which indicates that applying the flipped classroom model gives students greater opportunities to actively assess and evaluate their understanding of the learning material. Through the feedback feature (Feedback) available in the digital platform used, students can identify the parts of the material that they have mastered and the aspects that still need further understanding. This ability to obtain feedback independently fosters constructive self-reflection, encouraging students to evaluate their learning progress on an ongoing basis. In addition, this feedback mechanism also contributes to increased motivation

and the development of more effective learning strategies, as students can directly relate their learning outcomes to the efforts and approaches used in the learning process.

CONCLUSION

The findings from this systematic literature review indicate that TEL has a significant impact on the professional development of pre-service mathematics teachers. TEL not only enhances their teaching skills but also positively influences their cognitive, affective, and psychomotor domains. Firstly, TEL improves cognitive skills by enhancing problem-solving, mathematical reasoning, and critical thinking. Pre-service teachers who engage with TEL demonstrate stronger teaching competencies and technology integration skills, which are essential for modern educational environments. Secondly, in the affective domain, TEL boosts motivation and self-efficacy among pre-service teachers. The use of technology in teaching fosters a more engaging and interactive learning environment, reducing anxiety and increasing confidence in using digital tools. Thirdly, in the psychomotor domain, TEL develops pre-service teachers' digital skills, crucial for the 21st-century classroom. Although this study provides a comprehensive synthesis of the effects of TEL use on pre-service mathematics teachers across cognitive, affective, and psychomotor domains, it relies on secondary data without direct empirical validation. Consequently, the causal relationship between TEL implementation and the development of pre-service mathematics teacher competencies remains inferential rather than conclusive. Thus, future studies are encouraged to address this limitation by conducting empirical research employing experimental, quasi-experimental, or longitudinal designs to measure the long-term effects of TEL on teacher education outcomes. Future investigations should also explore the pedagogical implications of emerging technologies, such as artificial intelligence, virtual reality (VR), augmented reality (AR), and adaptive learning environments, for enhancing the teaching competencies, creativity, and digital literacy of pre-service teachers.

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