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A SLR: INTEGRATING TECHNOLOGY IN MATHEMATICS EDUCATION: THE IMPACT OF TPACK, PROFESSIONAL DEVELOPMENT, AND STUDENT ENGAGEMENT ON LEARNING OUTCOMES

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ABSTRACT

The Technological Pedagogical Content Knowledge (TPACK) framework is used in this systematic literature review to investigate how technology might be integrated into mathematics teaching. The study's objectives are to look into how professional development affects teachers' capacity to use digital tools in the classroom, analyse how technology can improve student engagement and problem-solving abilities, and pinpoint the obstacles that stand in the way of effective technology adoption. The study tackles the issue of inefficient technology integration, which is caused by disparate views towards digital technologies, insufficient institutional support, and poor teacher preparation. From a starting pool of 474 papers, 69 pertinent research were chosen using the PRISMA methodology. Results show that teachers who successfully incorporate technology improve learning outcomes and student engagement when they receive ongoing professional development support. Nevertheless, barriers such as inadequate institutional support and technical challenges continue to impede progress. The study concludes that tailored professional development programs are vital for enhancing teachers' technical and pedagogical skills. Furthermore, institutional backing and a positive disposition toward technology adoption are crucial for its sustainable integration within classrooms, ultimately leading to improved outcomes in mathematics education. Significance of study include bolstering teacher training initiatives and ensuring the availability of sufficient resources to support technology-enhanced learning environments. By addressing these areas, educators can be better equipped to navigate the complexities of integrating technology into their teaching practices, thereby enriching the educational experience for their students.

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INTRODUCTION

Technology adoption in the educational environment particularly mathematics has made it necessary to include algorithms, as they facilitate in enhancing student engagement and increase the overall academic skills. Technological Pedagogical Subject Knowledge (TPACK) is the pedagogy preparing framework that emphasises the intricate association among technology, pedagogy, and subject knowledge that offers a critical lens for educators operating in this complex world. Recent studies discovered that the inclusion of digital tools as long as it is successfully integrated into lesson plans by teachers would enhance students' problem-solving ability, intrinsic motivation, and engagement (Kim et al., 2021; Kriek & Coetzee, 2021). However, successful technology integration requires more than just providing the fastest connection — professional development programs must be conducted, which empower teachers to work confidently with these tools and inspire them to teach differently.

Secondly, the use of technology in the classroom depends heavily on how teachers perceive their role as mediators of technology. Technology integration makes tasks difficult as of lesson planning issues and communication breakdowns (Moreno et al., 2020; Stein et al., 2020). These challenges need to be rectified for the technology that is available to be used effectively in the classroom and enhance the learning experience of students as a whole.

The purpose of this systematic literature review is to investigate student engagement and learning outcomes in mathematics education using the TPACK framework to incorporate technology. The project is exploring the impact of professional development on teachers' ability to integrate digital tools, looking at how technology might improve student engagement and problem-solving, and examining barriers to their use. The current study aims to address this important gap by synthesizing the contemporary literature on technology integration, teacher preparation (DeGennaro & Forzani, 2020) and TPACK to provide key insights into leveraging technology for enhancing teaching practices and student achievement in mathematics (Kasapoglu et al., 2015; KHURRAM & AKGÜN, 2023).

LITERATURE REVIEW

Technology integration in mathematics education has been a prime focus area recently with the lens of the Technological Pedagogical Content Knowledge (TPACK) framework. This approach emphasizes how pedagogy, technology and subject matter expertise need to work together with each other. Research have illustrated that using technology in math classes improves significantly the critical thinking, problem-solving, and engagement skills of students (Kasapoglu, 2021; Kim et al., 2021). Studies have demonstrated that digital platforms and robot tools can not only support the understanding of difficult mathematical concepts but also provide students with engaging and rich environments. Nevertheless, to make use of TPACK effectively teachers require ongoing professional development in order to foster their technological and pedagogical expertise. What this study means is that teacher retraining has to be high quality in order for teachers to not only use these tools but to also fill them into their lesson plans. For these technological advances to translate into a great benefit for students, an individualized approach is key (Moreno et al., 2020).

But there are challenges to fully integrating technology in the teaching of mathematics, even with all the benefits. For this reason, classroom management is often under challenging conditions: minimal school support, insufficient training, and personal technology preference which may inhibit effective classroom dynamics (Kriek & Coetzee, 2021). Teachers' perceptions about these tools (usefulness and efficacy) also impact their adoption in classrooms because it influences how ready and capable they feel to integrate technological tools into their teaching frameworks. The studies also demonstrate the importance of overcoming these barriers by increasing teachers' technology confidence and providing them with resources and support networks necessary to navigate lesson planning problems associated with fostering student engagement. Therefore, it is clear that in order to support the success of technology integration, an intentional attempt must be made to provide teachers with continuous professional development, access to rich resources and a supportive educational environment (Khurram & Akgün, 2023).

The literature review will also discuss definitions associated with TPACK, Professional Development, Student Engagement and Technology Integration.

TPACK (Technological Pedagogical Content Knowledge)

A model that incorporates effectively content knowledge, pedagogy and technology to support teachers in the use of digital resources in their lessons. This was given by Kasapoglu (2021).

Technology Integration

Digital tools with robotics, coding and socials media platforms & teaching practices are integrated to increase student motivations as well as improved learning outcomes achieve (Kim et al., 2021)

Professional Development

To improve their digital literacy and practice innovative didactics in schools, teachers are continuously trained and supported (Moreno et al., 2020).

Student Engagement

Opportunities for human potential through effective teaching characterize student motivation, participation in the learning process, and development of critical thinking and problem-solving skills (Kriek & Coetzee, 2021).

METHODOLOGY

The PRISMA Framework-based Systematic Literature evaluation procedure comprises three main steps—Identification, Screening, and Eligibility —and each of the steps provides a holistic evaluation. Here, a more detailed description of each of these procedures is provided in the following subsections. Data Abstraction and AnalysisThis section delineates the review process, as defined by the PRISMA Framework once data has been formed.

Identification

The systematic review methodology consists of three major steps, which are essential to be able to gather an appropriate body of literature relevant to this study. The first stage involves identification of keywords and examination of related, equivalent terms via lexicons, thesauri, encyclopedias and previous academic investigations. Once the keywords had been identified, search strings were developed to query Scopus, WoS, ERIC and Google Scholar following the proposed EQUATOR checklist for research scoping reviews (Table 1). Methods continued using the method of systematic reviews, searching Ovid Medline 1946 and Embase 1974 through EBSCOhost for peer-reviewed literature on PLA over postsurgical physical activity from inception to May 2019 was inevitably ended up with appraising and appropriately extracting relevant data from a total of 474 scholarly articles: Phase I in completion.

Table 1
Search String

Database	Search String
Scopus	("TPACK" OR "technological pedagogical content knowledge" OR "technology integration in education" OR "digital teaching framework") AND ("math teacher" OR "mathematics educator" OR "math instructor")
WoS	("TPACK" OR "technological pedagogical content knowledge" OR "technology integration in education" OR "digital teaching framework") AND ("math teacher" OR "mathematics educator" OR "math instructor")

ERIC	("TPACK" OR "technological pedagogical content knowledge" OR "technology integration in education" OR "digital teaching framework") AND ("math teacher" OR "mathematics educator" OR "math instructor")
Google Scholar	("TPACK" OR "technological pedagogical content knowledge" OR "technology integration in education" OR "digital teaching framework") AND ("math teacher" OR "mathematics educator" OR "math instructor")

Screening

By screening at the initial phase, one article was removed as it contained duplicate entries. 157 papers entered the second screening phase, where scholars had been very careful to filter out publications using their specific selection and rejection rules. Because research papers are the main source of applied learning, the nature of the literature emerged as the primary assessment criterion. The process was also that which excluded reviews (not systematic), and the following: books, book series, meta-analyses, meta-syntheses or book chapters out of step with most contemporary research. However, this is important to note that these criteria were limited to the English language publications and covered only those work published in 2019–2023. These rigorous criteria led to the exclusion of 316 studies. Of these, 157 articles are thus for further evaluation of eligibility in the second phase as presented in Table 2.

Table 2
The selection criterion of searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2019-2024	< 2019
Literature type	Journal Articles and Conference Proceedings	Book Chapters, Book Series, and Reviews
Publication Stage	Final	In Press

Eligibility

In the review of the eligibility, 157 publications were found in phase 3. These papers needed to meet the inclusion criteria and had to complement the aims of the current study. Thus, 88 publications were removed from the screening because they did not meet certain criteria such as off-site publication reports, irrelevant sampling with the review aim or lack of relevance directly to substances and objectives mentioned by the researcher. Finally, Table 3 puts forward that an evaluation is possible based on 69 available publications.

Table 3
The selection criterion of Eligibility

Criterion	Inclusion	Exclusion
Sampling	Secondary Mathematic Teacher	Primary Mathematics Teacher, Students
Objective	TPACK, Online Platform, Teachers' pedagogy, pedagogy and competence in teaching Mathematics using TPACK	Tools, Robotics
Subject	Mathematics	Other than mathematics subjects

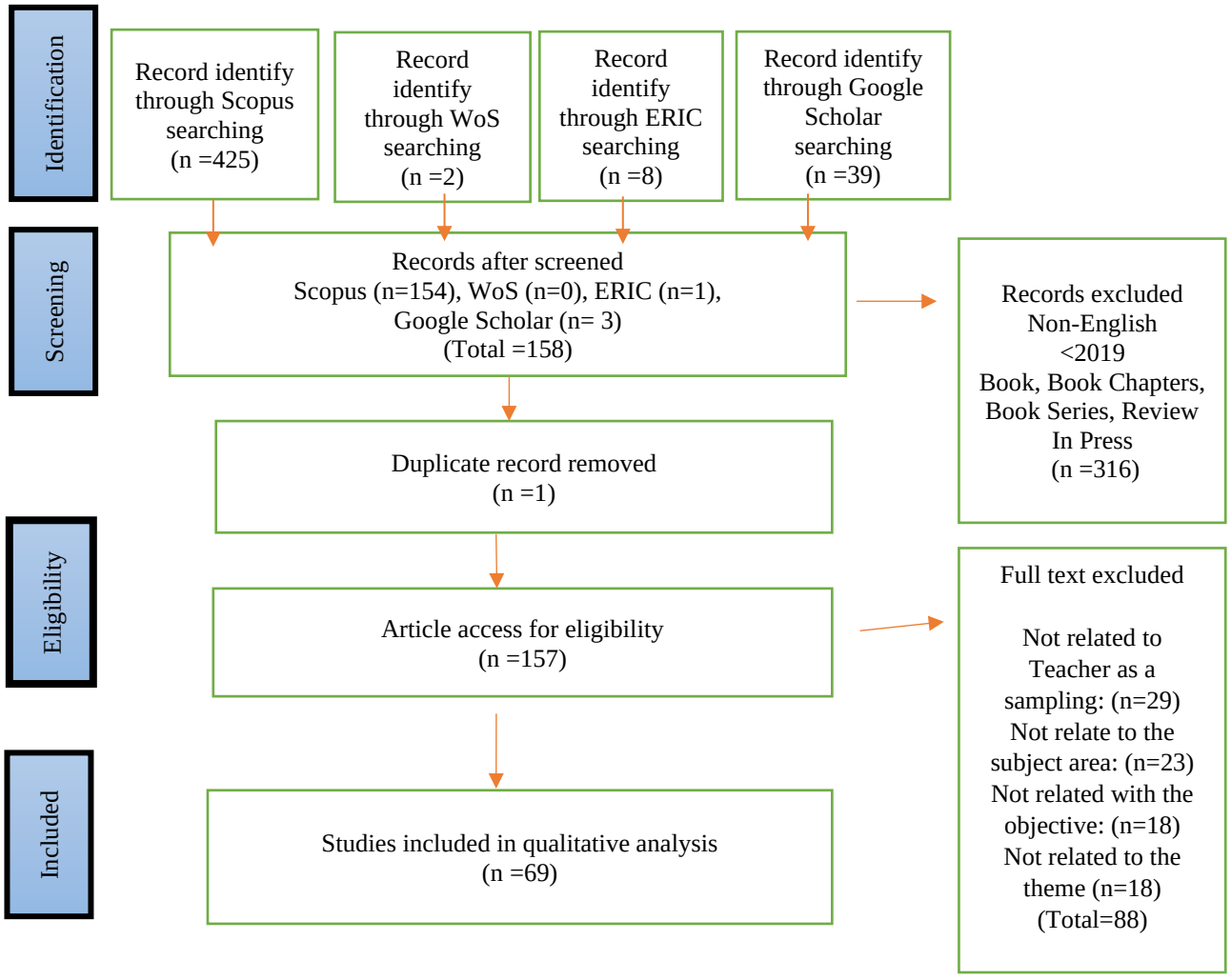
Data Abstraction and Analysis

Methods For this investigation, we used an interdisciplinary approach that included a mix of methodologies such as qualitative, quantitative, and mixed methods analysis. Specific objectives were to locate pertinent topics, and subtopics that related to how TPACK supported teacher capacities, subject matter knowledge and technological pedagogy. Data extraction and results 69 studies were critically reviewed to extract relevant information based on the key dimensions of interest for this study. This review yielded three broad categories: teacher training and professional development; student learning and engagement through teachers on online discussion board posting; and teachers' use of technology-enhanced pedagogical knowledge (TPACK). Given their joint efforts, the

authors could elaborate in these topics and concepts. All data analyses, conclusions, questions and other important findings were recorded in detail during the analysis of each login history.

The authors engaged in thorough discussions to ratify any disagreement that arose during theme development to ensure the credibility of the thematic procedure. Educational Technology (EdTech), Technology Pedagogical Content Knowledge (TPACK), and STEM Education experts vetted this analysis for domain validity, meaning they reviewed the sub-theme for trained relevance, appropriateness, and clarity. Professional insights and recommendations were incorporated into the analysis at different points during this expert review phase, which resulted in changes that enhanced the credibility and dependability of the study. Figure 4The preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram describing our procedure.

Figure 4.
Flow diagram of the proposed by (Moher et al., 2009)



This study is of a non-clinical-based nature and is based on the research technique document analysis as the main methodology, which conceptually aligns with this literature review. The exploration began by reading widely in the mathematics education literature to investigate a range of important lines of concern established in scholarly work. These themes included the nature of student engagement and learning in mathematics from the point of view of mathematics educators, the role that professional development plays in enhancing teacher efficacy and embedding technology within applicable pedagogical practices alongside concepts surrounding the Technological Pedagogical Content Knowledge (TPACK) framework. The study will focus on these core topics to provide deep insights into the impact technology is making on mathematics education, impact educators, and enhance student learning. Throughout this process, only relevant articles in major journals were carefully

evaluated for quality from reputable sources such as Google Scholar (https://scholar.google.com/), Scopus (Scopus, https://www.scopus.com/search/form.uri?display=basic#basic), Web of Science Journal list (Journal lists are found here, https://mjl.clarivate.com/search-results) and ERIC. After more systematic search, we retrieved 474 publications related to TPACK in math instruction by use of keywords. Through a rigorous review and elimination process that eliminated books, book reviews, non-English publications, and studies not published pre-2019, the final target list included 157 articles. After removing studies not directly related to the aims of TPACK or which were unrelated to mathematics, abstract and title screening eliminated 69 studies. The following papers highlight the importance of TPACK for enabling math teachers to better leverage more interactive and engaging learning environments. In 15% of articles, the issue was addressed directly by investigating technology-enhanced pedagogical knowledge (TPACK) in the mathematics teaching and emphasizing problems with teacher education and professional development. The bottom line is that teachers need to be dynamically changing and updating their teaching paradigms in order to facilitate engagement-cum-motivation of Mathematics learning by the students. Most of the sample publications focused on TPACK integration to maths instruction in Malaysia with another few that recognized and supported this methodology.

RESEARCH FINDINGS AND DISCUSSIONS

Using the three major themes as a foundation, the researchers will explore how important student engagement and learning are in mathematics education and why it is imperative that teachers use technology. These are student learning and engagement, teacher training and professional development, and technological pedagogical content knowledge (TPACK). Thus, the study will search how the TPACK is known as a pedagogical guideline for using technology in the classroom with a view to assist teachers to be able to overcome obstacles and then motivating students more (Gurer, 2021).

Theme 1: Student Learning and Engagement
Findings:

Technology in the classroom is necessary for piquing student curiosity and increasing performance across all subjects. For example, robotics can be used in mathematics education so that students gain an understanding of fundamental mathematical ideas through active and experiential learning (Kim et al., 2021). Moreover, the process of communicating and delivering information was challenging during the pandemic, thanks to social media like Instagram it proved useful in keeping students excited (El Amine Ghobrini et al., 2021). Also, it has been shown that problem-based learning and flipped classroom improve the students' ability in solving problems and their academic performance as well (Pimdee et al., 2024). But, in order for these tech tools to integrate effectively, that traditional teaching method needs to change. having the right support can be a daunting task. Discussion & Implications: Table 4 provides a summary of findings for the analysis in brief.

Table 4
Theme 1 : Student and Learning Engagement

Author(s)	Key Findings	Methodologies
(Kim et al., 2021)	There have been dramatic changes over the years in American maths classrooms.	general research approach to optimize educational resources.
(El Amine Ghobrini et al., 2021)	Social media learning is a fresh educational method which provides new online e-learning methods and ways to experience, it states specially in these trouble free situations of COVID-19 Emergency.	Methods: An exploratory survey-based study was initiated.
(Pimdee et al., 2024)	This project aimed to develop a learning model based on blended problem-based learning (PBL) in the online flipped classroom to enhance academic achievement (AA) and problem-solving skills (PSS) of Thai learners and teachers.	educational resources for general research approach.

(Stein et al., 2020)	This study focuses on the attitudes of novice math teachers towards technology integration in their classrooms.	broad research approach with resource for education.
(Kriek & Coetzee, 2021)	However, student feedback on technology use in the classroom differs from instructors; their feelings inform the approach that educators take and also influence student learning.	General Research approach for education resources.
(Zeeb et al., 2019)	Among the challenges for preservice teachers is integrating different types of knowledge like subject-specific pedagogical knowledge and pedagogical psychology knowledge.	broad research process with learning resources.
(Ansah et al., 2020)	The Senior High Schools (SHS) in Ghana is faced with a low level of mathematics achievement which has become a worry to various stakeholders.	Broad research approach with common educational resources
(Alsaleh et al., 2019)	In recent times, the attention has shifted to improving student learning outcomes by enhancing the quality of the teacher.	general educational resources and research methods.
(Pila et al., 2022)	A tablet is one such platform which is very exciting the way we teach science, technology, engineering and math (STEM) in early childhood classrooms.	General Research Methods and Educational Resources
(Ndlovu et al., 2020)	Specifically, the investigation focused upon preservice teachers (PSTs) and PST attitudes toward future intentions to incorporate information and communication technologies (ICTs) in their maths classes.	pilot surveyRefCount of an exploratory study
(Foster & Shah, 2020)	This analytical paper, however, based at testing a particular conceptual framework, is making an argument on central role of teachers in game-based learning (GBL) interventions.	A large research initiative plus teaching resources.
(Clark-Wilson et al., 2020)	We overview research surveys which have been conducted into the use of technology for mathematics learning in schools, focusing on this level.	an exploratory study using a survey approach.
(Marange & Adendorff, 2021)	Apparently this research investigate the preparatory algebra education and learning of Rank 8 students by trying to play online maths games.	general research approach with educational resources
(Alhamed & Ohlson, 2021)	The entire world has witnessed a revolution technology across all sectors, education being the most effected and hit area globally and same is the case with Saudi Arabia.	General principle guidance, with specific education articles.
(Yeo et al., 2022)	To break the courage and trust of each other, it is a very important job to get cgpa climb. Only one form of learner will experience an increase in attitudes called Digital Game-Based Learning by changing the points of dispute with them.	Approach to General Research with Collection of Educational Resources

Discussion:

The key findings regarding student learning and engagement can be found in Table 4. These findings are a reminder that technology and pedagogy need to go hand-in-hand to enhance student engagement. An illustrative

example of the recent trends in how to develop mathematics instructional and learning for critical thinking and problem-solving is to introduce new ways like through robotics at an early age, this way students play and reflect while playing (Kim et al., 2021). Furthermore, the increase in using social media for educational purposes during emergencies, demonstrates how important it is to provide flexibility when teaching methods are considered, albeit at a cost of potential challenges in communication (El Amine Ghobrini et al., 2021). We need to provide teachers with sustained support and professional development so that they can navigate the complexity and ensure their preparedness to use technology productively, while addressing its associated challenges.

Theme 2: Teacher Training and Professional Development

Findings:

Teachers who are well prepared is essential for implementing technology in the classroom effectively. In fact, what has been shown is that if teachers are not comfortable with digital media for their flipped classroom experiences, then the quality of those experiences will be greatly compromised (Moreno et al., 2020). Also, it is important that teacher training programmes value technical skill sets as much as teaching skill sets [KHURRAM & AKGÜN, 2023]. In particular, preservice teachers often do not have the epistemic need to link the mathematical study with teaching strategies (Castro & Pino-Fan, 2021). The findings are outlined in Table 5 below:

Table 5
Theme 2 : Teachers Training and Professional Development

Author(s)	Key Findings	Methodologies
(Moreno et al., 2020)	In this study, we aim to understand how math teachers' TPC influences their preparation of the instructional films necessary for implementing a flipped classroom model.	Broad Research Strategy including Resources for learning
(KHURRAM & AKGÜN, 2023)	At that point, the analysis intended to understand acceptance of information and communication technologies by high school teachers as well as their techno pedagogical educational capacity.	overall research method used: educational resources
(Castro & Pino-Fan, 2021)	Background: There is an increasing awareness of the necessary knowledge a math teacher should have by now.	File Type: PDFgeneral research approach with education information.
(Zambak & Tyminski, 2023)	In this article, the writers explore how teachers' content knowledge of teaching mathematics is influenced by instructional technologies and mediated by context, experience and those factors that reflect ideas about practising, technology and mathematical technology.	simple research strategy for studying materials
(Salviejo et al., 2024)	Helping future maths teachers in the Philippines to develop better critical thinking abilities is increasingly relevant, emphasising the requirement for tailor-made teaching.	Survey based exploration study
(Canlas, 2023)	This study also investigated how teaching efficacy, STEM career awareness, attitudes, and preparedness to teach in the field of STEM were related.	In general this is what carries the originality in research even with educational resources.

(Hong et al., 2019)	There has long been a consensus within the educational research community that the establishment of knowledge-building environments (KBEs) that can nurture learners towards acquiring essential skills required to live successfully in this era of information age, is an important targeted goal by many educators (Chen & Hong, 2016). This, however, raises another question: what specific types of qualities and skills do educators need to display in their practice to foster these KBEs	Common Approach to Educational Resources.
(Pourdavood & Song, 2021)	Many in-service and pre-service maths teachers reported inadequacies and being unprepared for the pedagogy to take place online during the COVID-19 pandemic.	more general research or educational vibe.
(Love & Hughes, 2022)	Developing the content and pedagogical knowledge of pre-service teachers is needed to provide this level of STEM (science, technology, engineering, and mathematics) education.	A survey-based explorative study.
(Naidoo & Govender, 2019).	Pre-service teachers must acquire high-quality STEM (science, technology, engineering and mathematics) education to develop their content and pedagogical knowledge.	A general research guide that includes educational resources
(Pham et al., 2023)	How effective are teachers at teaching remains a key benchmark by which most high schools are judged.	Broadly researched technique having Edu assets.
(Putra et al., 2021)	The necessity digital integration in education continues to increase as is evident considering the Covid-19 pandemic.	Research or study done by common educational resources
(Tran et al., 2020)	This looks different, sure, but that is only due to a system of competencies laid out for pre-service teachers since the 1930s teaching future teachers.	broader research process with learning material
(Agyei et al., 2022)	The purpose of this study was to investigate high school teachers' competencies (i.e., preparedness, knowledge, skills and self-efficacy beliefs) in using technology to deliver mathematics instruction.	Interview constituent_recipient beneficiary service_ receiver_policy_holder_qualitative research
(Newton et al., 2022)	A vast research literature has established that the nature of the knowledge that maths teachers in their work differs from that of those in other professions.	a general research approach with educational resources.
(Ortega-Sánchez et al., 2020)	This article addresses how preservice teachers (n = 162) perceive their competence in the CCD as they engage in preparation for the CCD during initial teacher education.	Meaning more broadly applicable for educational resources nature of research.
(Connolly et al., 2021)	There is limited research on the use of mobile learning supported with computational thinking, which in turn is less explored in initial teacher education (ITE) level.	basic research methodology with backstory

(Baek & Sung, 2020)	Preservice teachers are expected to learn about technological literacy and competences as part of their teacher education programs, since more technologies are available for teaching and learning purposes.	Educational Resources on General Research Approach
(Backfisch et al., 2020)	The expert pool for a study on proficiency contained 94 maths teachers with diverse degrees of relative teacher expertise participating.	a general research with educational resources You Theme
(Sebsibe et al., 2023)	The greatest in-school influences on students learning outcomes come down to their teachers.	high level view of research with learnings.
(Tashtoush et al., 2022)	The main aim of this study is to investigate pre-service math teachers' habits of mind and relation between their habits of mind and mathematical reasoning abilities after a training program based on trends in international mathematics and science study (TIMSS) in Oman.	high-level research method with learning materials.
(Irshid et al., 2023)	A training program based on principles that foster concept understanding within a math teacher knowledge development program was evaluated to better understand how it influenced the pedagogical mindset of participating math teachers.	view the research performed with educational resources.
(Gurer & Akkaya, 2022)	Although pedagogical assumptions may strongly affect the acceptance of technology in education systems, few of the current technology acceptance models (TAMs) seem to analyze this aspect.	generic educational; layout
(Shreiner & Guzdial, 2022)	This paper will describe musings that emerge from collaborative workshops organized by pre-service and in-service social studies teachers collaborating in participatory design as part of a project to develop a pedagogical support system for teaching data literacy.	Research strategy with study materials.
(Osei & Agyei, 2024)	Because math class is changing with the increased use of technology, it is an excellent time to learn what foundational knowledge you need as a teacher to be successful at blending technology into algebra lessons.	a comprehensive research approach melded with curated teaching material.

Discussion:

Highlights for the theme of Teachers Training and Professional Development are presented in Table 5. These findings emphasize the necessity for educational technology innovation to be viewed through a strong pedagogical lens by professional development designs. Much of the same results in being more interesting are true as well for having better technological competency — such that teachers who have higher levels of tech proficiency also create lessons and activites that students enjoy (Moreno et al. 2020). Nevertheless, the current lack of pre-service teacher preparation points to a need for more targeted programs that enhance technical and pedagogical skills. Such programs are necessary in order to provide educators with the resources they need to both make STEM education innovative and interesting as well as create an interactive environment of learning.

Theme 3: Technological Pedagogical Content Knowledge (TPACK)

Findings:

The TPACK framework is well-accepted as a critical factor in the integration of technology with teaching. In approaches that encourage student interaction, teachers comfortable with technology perform better (Gurer, 2021). There is still a problem with Technological Pedagogical Mathematical Knowledge (TPMK) as teachers struggle in designing inquiry-based lessons (Koh, 2019). Additionally, working with software such as the GeoGebra program improves teachers' readiness to use technology in the classroom (Açıkgül & Aslaner, 2020). Summary Of The Results in Table 6

Table 6
Theme 3: TPACK

Author(s)	Key Findings	Methodologies
(Kasapoglu, 2021)	The aim of this study is to research the qualitative and mixed research on pre-service and in-service science teacher knowledge studies that have been conducted in Turkey between 2015-2019.	learning resources for general research approach
(Koh, 2019)	Studies reveal that teaching maths lessons which are integrated with technology and promote mathematical inquiry within real-life contexts has been quite a challenging aspect for most maths teachers.	Keyword Research Guide Keyword Mining with Educational Resources
(Açıkgül & Aslaner, 2020)	The context of the study is on how TPACK game practices and micro-teaching applications supported with GeoGebra influence prospective math teachers on their self-efficacy beliefs and TPACK efficacy perceptions.	General Research Approach with School Resources
(Backfisch et al., 2024)	To realize such meaningful technology-integrated teaching, teachers need to systematically combine the knowledge of content and pedagogy with their knowledge of technology.	Common research methodology for education purposes.
(Gurer, 2021)	Interpreted from the perspective of educators, student adoption is key to how wholeheartedly technology can better fit into the classroom.	General education resources that were used by the research group.
(Morales et al., 2022)	The purpose of the study is to investigate the experiences and practices of teachers in STEM (science, technology, engineering, mathematics) areas using a TPACK,: Technological Pedagogical Content Knowledge perspective.	Public research strategy — a bootleg education program.
(Mansour et al., 2024)	Enabling science and math teachers to teach integrated STEM classes requires developing content-specific mastery as well as pedagogical skills.	generic research process to Educational sources.
(Gurevich & Barchilon Ben-Av, 2023)	The aim of the present study was to investigate how students across different mathematics courses responded when technology was used.	Educational resources used for general research_approach

(Said et al., 2023)	This essay is part of a project designed to enhance STEM education through improved teacher professional development (TPD).	Educational resources with general research approach.
(Estrada-Molina et al., 2022)	We were interested both in what new knowledge bases these activities drew on when working through new technological tasks and noted that this could serve to analytically locate the appropriateness of such activity for teaching mathematics.	a broad approach to researching educational resources.
(Adelabu & Alex, 2022)	The new technologies have led to a change in many aspects of mathematics education, and one of the most obvious is the way we teach mathematics under these conditions that characterize life in the twenty-first century.	pedagogical research design.
(Driskell et al., 2023)	The tool I developed to collect information about the experiences of mathematics teacher educators (MTEs) moving from face-to-face to emergency remote teaching (ERT) is named Mathematics Teacher Educators' Migration to Online Teaching in Response to COVID-19.	general research approach with educational resources.
(Apriandi et al., 2023)	Background and aim of the study	Exploratory survey-based analysis.
(Aini, 2024)	However, what is of importance to us is for teachers to develop the fundamental knowledge that is known as TPACK (Technological Pedagogical and Content Knowledge).	Research Plan & Educational Resources
(Bergeson & Beschorner, 2020)	This case study is focused on PSTs' efforts to plan for digital technology integration as they developed an understanding of how to implement their emerging TPACK while organizing literacy instruction.	It illustrates a general research approach with steps, adding educational resources.
(Kartal & Çınar, 2024)	Its called Technological Pedagogical Content information (or TPACK), and youre probably familiar with the background of the word.	research process with some other educational resources.
(Rodríguez-Muñiz et al., 2021)	The coronavirus disease 2019 (COVID-19) was responsible for a wall-to-wall switch over to emergency remote teaching (ERT) throughout the world, bringing an end to classroom-based instruction everywhere.	Educational Resource... General research approach.
(Čipková et al., 2024)	Today, with the significant stride science and technology have made, there is a rightful need to integrate technologies in an ethical way into the educational system.	A general educational resources research approach.
(Agyei et al., 2024)	The teacher surveys have reported very low levels of technology integration into the delivery of mathematics lessons in Ghanaian Senior High Schools where there has been high proliferation of educational technologies.	interview based,QUALITATIVE RESEARCH

(Ozudogru & Ozudogru, 2019)	The use of technological tools and resources in K–12 settings worldwide is becoming increasingly ubiquitous, which means that it has become necessary to assess the technological pedagogical content knowledge (TPACK) levels of maths teachers. I say this because the use of technology in teaching mathematics opens new doors for students that can enhance their motivation and interest-level.	General strategy for research with academic resources
(Patriarca et al., 2019)	This article reports a study snippet on course development for 600 high school math teachers working in province of Paulo state, Brazil to be taught through ongoing distance learning.	general phases of research and more learning resources.
(Thohir et al., 2023)	While virtual reality (VR) is somewhat a development from the learning metaverse, it remains to be seen how much VR will be accepted in terms of furthering technical pedagogical content knowledge AKA TPACK.	widely accepted research approach for educational resources.
(Hall et al., 2020)	Despite the popularity of flipped teaching in higher ed, its conceptual basis has not been widely utilized within teacher education programs.	Research with educational reference.
(Muhtadi et al., 2017)	The present research reveals the Transformation of Technological Pedagogical and Content Knowledge (TPACK) of three prospective maths teachers.	general research approach with educational resources.
(Manganyana et al., 2020)	This study intended to evaluate the effect on student experience and achievement of teachers just back from GeoGebra trainings.	resources associated with research of any kind.
(Ifinedo & Kankaanranta, 2021)	Keep in mind the teachers perspective when it comes to using technology in the classroom.	All in all some research, but will resources from the education side.
(Fabian et al., 2024)	In this age of digitalisation, it is essential that pre-service teachers are given ample opportunities for professional development to further enhance their knowledge and comprehension of how technology can be integrated into teaching and learning environments.	an extensive research approach with educational assets.

Discussion:

Results from the TPACK theme can be seen in Table 6. Given these results, TPACK competence is required of new educators and in the curricula as a whole in the present-day education, especially in STEM areas. One of the most important determinants in this respect is how confident are the teachers when it comes to being able to use technology for crafting relevant lessons (Gurer, 2021). One way to overcome these obstacles in terms of ICT integration is by providing professional development programs, especially those focusing on hands-on experience with technology so that teachers can be able to develop tailor-made use ICT in teaching.

CONCLUSION AND RECOMMENDATION

This systematic literature review investigates a) How the Technological Pedagogical Content Knowledge (TPACK) framework benefits student engagement and learning outcomes in Mathematics, the rest of this paper is organized as follows. The results proved that by implementing the TPACK model in teaching methods, motivation, problem-solving skills and overall commitment during the learning process of students greatly improved. Access to the tools is one thing, but successful implementation requires trained teachers, not only on how to use them effectively within their instruction in creating new learning opportunities but also granting the pedagogical flexibility and technical proficiency required. If they have this type of backup, teachers are more likely to integrate technology that boosts student fascination with any given topic. Teacher conceptual structures of technological resources as well as teacher challenges in lesson management and communication are major obstacles to the successful implementation of technology into classrooms. Such problems underline the importance of institutional backup, not only with regard to sourcing and providing the technology, but as importantly, encouraging teachers' greater comfort with managing the complexities involved in its use. Nevertheless, a highly skilled and motivated workforce to rely on so teachers can provide students with the science education benefits of a more active learning environment — one which could substantially increase student achievement – would help.

Based on the findings, school systems may wish to consider offering targeted professional development opportunities that meet the instructional and technological needs of teachers. Integrating Technology bursting time for Teachers to Learn Some courses and how they can help teachers learn to incorporate technology into student learning. Schools must also have strong support to help teachers work through the real-world realities around technology use in the classroom, from class prep to student engagement. If teachers feel more positively about their use of digital technologies, they will be more likely to implement it well, so attitudes towards technology are important to include.

Moreover, for teachers, the most demand is to be directly working with technology such as robotics and online platforms. These resources allow learning to happen at a higher level and support students understanding of difficult mathematical concepts in an engaging way. This type of hands-on experience provides teachers with a confidence boost to infuse technology more seamlessly into their lessons. There are some limitations of this study as well First and foremost, the scope of the review is narrow; because it postdates 2019–2024 only papers from these years. That means critical findings from prior studies can go unnoticed. The focus on secondary mathematics education and exclusion of broad-based basic education and other disciplines can offer thoughtful perspectives of how technology might be used better. The study design of EducationPath is national, thus its findings are largely generalisable to the Malaysian context based on our local curriculum, and may not reflect similar results in other places with different modes or systems of education. These findings raise the question of whether studies that focus on technology-rich schools and students can generalize to other settings, and reinforce the value of conducting additional research on the impact of new technology in education across such varying contexts.

In conclusion, using the TPACK framework for technology integration in teaching mathematics positively affects student learning and engagement. However, the dividends described will not be achieved unless teachers are provided with sustained help in terms of training and practical experiences with technology. Solving these issues will make it easier to remove walls which allow students to use technology inside the classroom properly and in Lastly, they would also improve their math class performance.

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