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Factors Influencing Mathematics Teachers' Blended Learning: A Systematic Review

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Abstract. Blended learning has emerged as an important practice in mathematics education in today's educational landscape. With technology reshaping teaching practices, it is critical to gain a better understanding of the factors influencing mathematics teachers in blended learning to increase teaching efficiency and student outcomes. This systematic literature review aimed at identifying and integrating factors influencing mathematics teachers' blended learning practices in current educational contexts. This review focuses on studies published between 2023 and 2024, which include the latest insights and advancements in blended learning. Using the preferred reporting items for systematic reviews and meta-analyses framework, this review analyzed 34 recent studies sourced from Scopus and Web of Science. The articles were selected based on inclusion criteria prioritizing empirical research on mathematics teachers' blended learning practices, while studies lacking empirical data or relevance to mathematics education were excluded. The findings were categorized into the three themes of teacher preparedness and perceptions; technological pedagogical content knowledge and instructional design; and student engagement, learning environment, and outcomes. The results importantly highlight the critical role of professional development, innovative instructional strategies to improve teaching practice, and student engagement. Persistent challenges, such as resource inequities and teacher training gaps, remain barriers to effective implementation. By focusing on recent studies, this review reflects the latest direction in blended learning. These findings provide information relevant to educators and policymakers to enhance mathematics education through blended learning.

Keywords: Systematic review; blended learning; blended teaching; blended environment; flipped learning

1. Introduction

Blended learning, which integrates traditional face-to-face instruction with online activities, has emerged as a transformative approach in mathematics education (Saichaie, 2020). By combining the benefits of in-person teaching with the flexibility and interactivity of digital tools, blended learning enhances student engagement, facilitates personalized learning, and fosters the development of critical skills (Chin et al., 2019; Kundu et al., 2021).

Key instructional models, such as the flipped classroom, mixed model, and online practicing model, offer diverse ways to address students' needs and improve mathematical thinking and problem-solving abilities (Lyakhova & Joubert, 2022; Staddon, 2022). These methods have proven effective in increasing student activity, engagement, and learning outcomes in mathematics education (Helsa et al., 2021; Tong et al., 2023). The widespread adoption of blended learning during the COVID-19 pandemic further demonstrated its potential to overcome the limitations of traditional teaching methods and its relevance in today's educational landscape (Kalogeropoulos et al., 2021; Mulenga & Marbán, 2020).

One of the strengths of blended learning is its ability to integrate technology into mathematics classrooms, offering opportunities to accommodate individual learning paths. Students can engage with differentiated content and receive personalized feedback, addressing their unique needs and supporting rich mathematical concept learning (Albano, 2011; Attard & Holmes, 2020). Teachers benefit from tools that enable more efficient communication and feedback mechanisms, enhancing their capacity to respond to students' queries and fostering interactive learning environments. Despite these advantages, the successful implementation of blended learning requires a balanced integration of classroom and online instruction (Abuhassna et al., 2022; Owston et al., 2019).

However, several challenges complicate the effective adoption of blended learning. Robust technological infrastructure is essential for success.; this remains a significant barrier in many resource-constrained settings (Capone, 2022; Yasin et al., 2020). Teachers also face challenges in adapting their instructional methods to blended learning environments, requiring professional development programs that emphasize the integration of digital tools and pedagogy. Without adequate training, teachers may struggle to create suitable content or develop the digital skills necessary for effective teaching (Ashraf et al., 2021; Bizami et al., 2022).

Moreover, students may experience difficulties with self-regulation in blended environments, leading to reduced engagement and inconsistent knowledge acquisition. These barriers highlight the importance of addressing both technological and pedagogical gaps to maximize the potential of blended learning (Derbush & Skarbich, 2021; Polly & Casto, 2019; Tan et al., 2023).
While existing research has highlighted the advantages of blended learning, there is a lack of recent, comprehensive analyses synthesizing its impact on mathematics education. Much of the literature focuses on general education, leaving the specific challenges and opportunities faced by mathematics teachers underexplored. Furthermore, as blended learning evolves, particularly after the widespread changes driven by the COVID-19 pandemic, updated insights are crucial for understanding its current and future applications.

2. Literature Review

One of the most prominent trends in the development of mathematics education is the integration of traditional and technology teaching methods. With the help of technology, blended learning offers flexibility, individual instruction, and enhanced engagement. Blended learning was found to be valuable, especially during the COVID-19 pandemic, which forced education systems to look for means of continuing to instruct learners (Kalogeropoulos et al., 2021; Mulenga & Marbán, 2020). Today, its significance remains evident since education systems operate more and more within the framework of the digital environment to fulfil the needs of students in the modern world (Engelbrecht & Borba, 2024).

Learning includes self-paced instruction and traditional classroom learning. The rationale behind embracing blended learning in mathematics education is important since understanding mathematical concepts and the ability to think critically and solve problems quickly are critical. Teaching approaches, such as flipped classrooms, combined with other approaches and supplemented by a variety of instructional methods, can be highly effective in improving students' interest and performance (Helsa et al., 2021; Lyakhova & Joubert, 2022). Those teaching practices provide an opportunity to carry out a differentiated teaching process, taking into consideration the needs of the students and their learning speeds. Various research shows that blended learning leads not only to increases in student outcomes but also to motivation and self-regulation (Attard & Holmes, 2020; Tong et al., 2023).

However, some challenges are encountered in the use of blended learning in mathematics education. The use of technology in the learning environment disrupts traditional teaching methods and requires teachers to bring changes to their practice (Clark-Wilson et al., 2020).

Prior literature contains important information on the applicability of blended learning but does not always have a focus on mathematics teachers (Indrapangastuti et al., 2021; Zhao & Song, 2021). Furthermore, additional research could provide more valuable insights into how aspects such as professional development, institutional support, and telecommunication technology converge to shape teachers' preparedness and attitude (Capone, 2022; Yasin et al., 2020).

Teacher professional development initiatives designed to improve teachers' knowledge of technological and pedagogical strategies have the potential to increase teacher self-efficacy regarding the use of blended learning in the classroom (Winarso & Udin, 2024). However, such initiatives are not uniformly distributed and major gaps in terms of teacher preparedness are observed in the areas with the lowest levels of access to resources (Nsengimana et al., 2024). Furthermore, while the technological, pedagogical, and content knowledge (TPACK) framework has garnered much attention as an effective knowledge-aid tool in effective blended learning implementation, especially among teachers, its implementation profile among mathematics educators remains limited (Helsa et al., 2021).

Despite the considerable number of studies published over the last two decades, there is a significant gap in the existing literature about factors affecting the implementation of blended learning among mathematics teachers. In a new era of education, post-COVID-19, it is valuable to know such factors to identify learning gaps regarding training, resources, and lesson planning. Extending prior research, this review is centered on the specific concerns of mathematics educators in their efforts to adapt to a blended learning teaching environment and provide guidance for their practice transformation.

3. Research Questions

The purpose of this systematic literature review is to synthesize factors affecting mathematics teachers' blended learning within the current educational context. Considering the requirements of the PICo (population, interest, context) structure, which was developed by Lockwood et al. (2015), the research question was conceptually formulated following the guidelines of the structure. The target population (P) consists of mathematics teachers since their preparedness, perceptions and strategies for handling a blend of conventional and online learning are critical to a successful implementation of blended learning. Interest (I) focuses on understanding the key factors shaping mathematics teachers' blended learning practices, including technological access, professional development, institutional support, and pedagogical integration. The context (Co) of current educational practices reflect the evolving use of pedagogical strategies in blended learning. The PICo framework ensures that the research question is precise, targeted, and aligned with the study's purpose, reducing bias and facilitating a structured review (Kitchenham, 2007). This study addressed the following research question: "What are the factors influencing mathematics teachers' blended learning in current educational practices?"

4. Methodology

When conducting a systematic literature review, the preferred reporting item for systematic reviews and meta-analyses (PRISMA) is used as a guide (Page et al., 2021). Using the PRISMA flow chart, researchers are presented with a clear framework for searching, assessing, and including studies in their synthesis process. This approach of organizing the search strongly focuses on reducing the amount of bias and improving the overall quality of, preferably randomized, studies.

In this review, two broad databases were found suitable to address this challenge: Web of Science (WoS) and Scopus. The PRISMA method is divided into four main steps as the components of the study: identification, screening, eligibility, and data extraction. Scopus and WoS are two major bibliographic databases. They are widely popular among researchers involved in systematic literature reviews because of the great number of journals and accurate citation indexes. While compiling articles, Scopus indexes more than 23,000 journals, as well as 120,000 conferences and WoS indexes more than 13,600 journals with data for the calculation starting in 1900 (Rahman et al., 2021; Singh et al., 2021).

WoS, provided by Clarivate Analytics, is known for its selectivity and time frame, which extends up to 20 years. Scopus, created by Elsevier, unites more subjects from different interdisciplinary spheres and contains more up-to-date citation data (Harzing & Alakangas, 2016). WoS is best at history analysis and papers with high-impact factors; Scopus is best for accessing emerging fields and various fields of study. Altogether, both sources present a comprehensive picture of the researched academic area, which is crucial while indicating the factors and trends in blended learning and ensuring a systematic review of the literature (Joshi, 2016; Mongeon & Paul-Hus, 2015; Pranckute, 2021). This guarantees that the research evaluations of Scopus and WoS are complete and balanced, considering the strengths of one and compensating for the weaknesses of the other.

4.1 Identification

This study used steps of the systematic review process where possible to compile a reasonable amount of research on the subject. The process started with choosing keywords and defining other relevant and similar terms drawn from dictionaries, thesauri, encyclopedias, or previous research. Concerning the target terms, all the matching expressions were gathered, and two search queries were developed for the WoS and Scopus databases, as presented in Table 1. Applying the aforementioned systematic review steps in this study, both databases provided 1,812 publications (Scopus, n=1089 and WoS, n=723) concerning the topic under study.

Table 1: Keywords and strategy to search for information keywords

Database search string	
Scopus	TITLE-ABS-KEY ((teacher OR lecturer OR tutor OR educator) AND (“blended learn*” OR “blended strategy*” OR “blended education” OR “b-learn*” OR “blended-learn*” OR “blend* learn*” OR “blended e-learn*” OR “blended learn* environment” OR “online learn*” OR “online teach*” OR “flip* teach*” OR “flip* learn*” OR “hybrid learn*” OR “hybrid teach*”) AND “mathematic*”)
WoS	TS=((teacher OR lecturer OR tutor OR educator) AND (“blended learn*” OR “blended strategy*” OR “blended education” OR “b-learn*” OR “blended-learn*” OR “blend* learn*” OR “blended e-learn*” OR “blended learn* environment” OR “online learn*” OR “online teach*” OR “flip* teach*” OR “flip* learn*” OR “hybrid learn*” OR “hybrid teach*”) AND “mathematic*”)

4.2 Screening

The selection entailed vigorous scrutiny of records obtained from Scopus and WoS databases. At the primary stage, 91 records were found: 68 from Scopus and 23 from WoS. The records used in this study were exclusively sourced from the Scopus and WoS databases for inclusion and exclusion, as shown in Table 2. In the screening phase, none of the study records identified were duplicated, so all the entries recorded were considered for further assessment (n = 91). Based on this, the inclusion criteria were articles with open access in the period between 2023 and 2024. The following exclusion criteria were then employed to exclude the studies that did not meet the requirements of the present review: any publication written in a language other than English, records published before

2023, and conferences, books, and review papers. Consequently, 1,721 records were omitted due to low compliance with those criteria.

Table 2: Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Language	English	Non-English
Timeline	2023–2024	< 2023
Literature type	Journal (article)	Conference, book, review
Publication stage	Final	In Press
Subject area	Social Science, Mathematics	Other than Social Science and Mathematics

4.3 Eligibility

The authors screened 91 articles to determine whether they met the criteria for being included in the review. This involved examining the title, abstract, and content of every identified article. This was done to check their applicability to the research objectives and to gain access to the full papers required for the comprehensive examination. Of this analysis, 57 articles were excluded since they did not emphasize the impact of blended learning of mathematics teachers and education. Other omissions were made whenever titles were inconsequential or the abstracts failed to meet the study's goals. Furthermore, our search was restricted to those articles that could be obtained as full text only; those that were not accessible in full were excluded from the study. A total of 34 articles were considered for analysis, as seen in Figure 1.

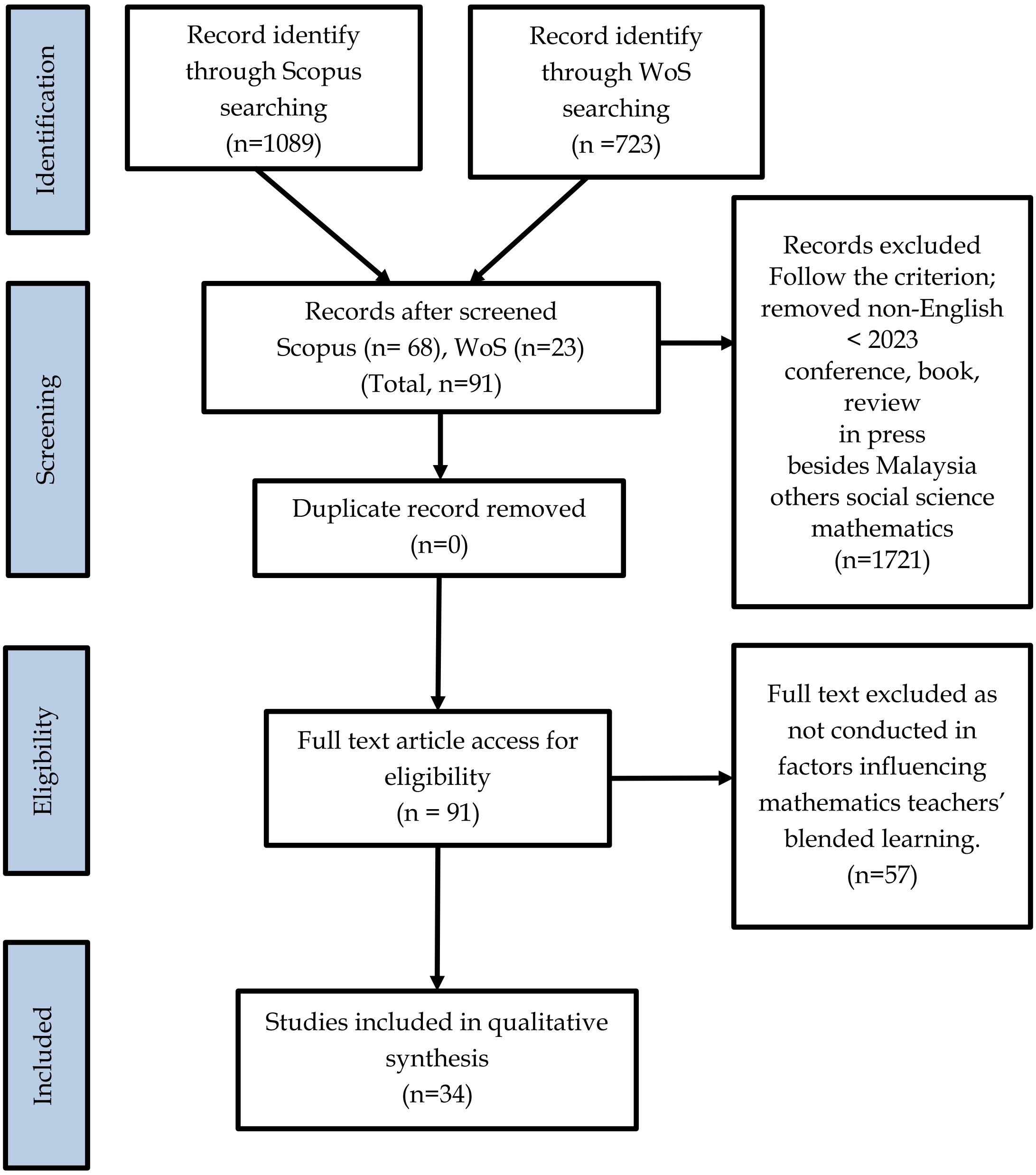

Figure 1: PRISMA flow diagram

(Moher et al., 2015)

4.4 Data Abstraction and Analysis

The selected articles were thoroughly analyzed to address the research questions. The articles were reviewed to identify key themes and subtopics. A qualitative content analysis was conducted to uncover patterns across 34 studies on blended learning. Based on a typology, the authors systematically organized the identified themes. The reviewers employed thematic analysis to consolidate and classify findings from previous research (Adams et al., 2021).

4.5 Quality of Appraisal

According to the guidelines from Kitchenham (2007), once primary studies are selected, their quality must be assessed and compared quantitatively. For this study, we adopted the quality assessment framework developed by Abouzahra et al. (2020), which outlined six quality criteria for our systematic literature review. Each criterion was evaluated using a scoring system: “Yes” (Y) for full compliance, earning 1 point; “Partly” (P) for partial compliance with some limitations, earning 0.5 points; and “No” (N) for non-compliance, earning 0 points. The quality of the selected studies was assessed using six criteria to ensure a thorough and objective evaluation:

QA1: Is the purpose of the study clearly stated?
QA2: Is the interest and usefulness of the work clearly presented?
QA3: Is the study methodology clearly established?
QA4: Are the concepts of the approach clearly defined?
QA5: Is the work compared and measured with other similar work?
QA6: Are the limitations of the work clearly mentioned?

These criteria offered an organized means of assessing the clarity and relevance of the study as well as its methodological quality and quality level. To advance to the next step, a study has to gain a total of more than 3.0 marks, compiled out of the scores given by all three experts, one in the systematic literature review, one in blended learning, and one in technology requirement. Each expert assessed the research study according to these criteria, and the results were summarized to get a final rating. This ensured that only the studies that met the quality standard set provided information during the next phase. The quality assessment table for the selected papers is seen in Table 3.

Table 3: Quality assessment for selected papers

No	QA 1	QA 2	QA 3	QA 4	QA 5	QA 6	T	%
1	1	1	0	1	0.5	0.5	4.0	67
2	1	1	1	1	0.5	0.5	5.0	83
3	1	1	1	0.5	0.5	0.5	4.5	75
4	1	1	1	1	0.5	0.5	5.0	83
5	1	1	1	1	1	1	6.0	100
6	1	1	0.5	0.5	0.5	0	3.5	58
7	1	1	1	1	0.5	0.5	5.0	83
8	1	1	1	1	1	1	6.0	100
9	1	1	1	1	1	0.5	5.5	92
10	1	1	1	1	0.5	0.5	5.0	83
11	1	1	0.5	0.5	0.5	0.5	4.0	67
12	1	1	1	1	0.5	0.5	5.0	83
13	1	1	1	1	0.5	0.5	5.0	83
14	1	1	1	1	0.5	0.5	5.0	83
15	1	1	0.5	0.5	0.5	0.5	4.0	67
16	1	1	1	1	1	0.5	5.5	92
17	1	1	1	1	0.5	0.5	5.0	83
18	1	1	1	1	0.5	0.5	5.0	83
19	1	1	1	1	0.5	0.5	5.0	83
20	1	1	1	1	0.5	0.5	5.0	83
21	1	1	1	1	0.5	0.5	5.0	83
22	1	1	1	1	1	1	6.0	100
23	1	1	1	1	1	1	6.0	100
24	1	1	1	1	0.5	0.5	5.0	83
25	1	1	1	1	0.5	0.5	5.0	83
26	1	1	1	1	1	0.5	5.5	92
27	1	1	1	1	0.5	0.5	5.0	83
28	1	1	1	1	0.5	0.5	5.0	83
29	1	1	1	1	1	1	6.0	100
30	1	1	1	1	1	1	6.0	100
31	1	1	1	1	1	0.5	5.5	92
32	1	1	1	1	0.5	0.5	5.0	83
33	1	1	1	1	0.5	0.5	5.0	83
34	1	1	1	1	0.5	0.5	5.0	83

The prominently developed themes were also brought to reasonable convergence. Thus, three experts analyzed the identified issues to check the quality of each subtheme and choose suitable options within the study's framework. A similar evaluation of the experts contributed to the verification of domain validity. When differences arose during the theme development process, the authors and experts worked together to review the findings, discuss the issues, and find a common agreement.

5. Results

The results presented in Table 4 are based on a thematic analysis of 34 articles, which involved coding the findings from the included studies, grouping related factors, and categorizing them into themes based on shared characteristics and similarities across components. This approach allowed for the identification of patterns and key factors that shaped the development of the themes, providing a comprehensive understanding of the elements influencing blended learning practices. The findings discovered three themes that influence mathematics teachers in blended learning. The first theme, Theme 1, is teacher preparedness and perceptions in blended learning. Theme 2 is TPACK and instructional design in blended learning, while Theme 3 is student engagement, learning environment, and outcomes in blended learning.

Table 4: Themes of factors influencing mathematics teachers in blended learning

<table>
<tr><th colspan="3">Authors</th></tr>
<tr><th>Theme 1</th><th>Theme 2</th><th>Theme 3</th></tr>
<tr>
<td>1. Glover and Stewart (2024)
2. Radmehr and Goodchild (2023)
3. Erianjoni et al. (2023)
4. Tunç-Pekkan et al. (2023)
5. Li (2023)
6. Callaghan et al. (2023)
7. Fujita et al. (2023)
8. Anwar et al. (2023)
9. Huang et al. (2023)
10. Engelbrecht et al. (2023)
11. Kunwar et al. (2023)
12. Morton and Durandt (2023)</td>
<td>13. Abdul Latif et al. (2024)
14. Karaca and Akyuz (2024)
15. Fitrah et al. (2024)
16. Toivola et al. (2023)
17. Backfisch et al. (2024)
18. Helsa et al. (2023)
19. Bautista and Valtoribio (2024)
20. Aini and Masrurotullaily (2024)
21. Wischgoll and Prediger (2024)
22. Kämpf and Stallmach (2024)
23. Matitaputty et al. (2024)
24. Gopalan et al. (2024)
25. Papach et al. (2023)</td>
<td>26. Millones-Liza et al. (2024)
27. Rueda-Gómez et al. (2024)
28. Yudt et al. (2024)
29. Wang et al. (2024)
30. Daher et al. (2023)
31. Liew et al. (2023)
32. Fauzan et al. (2023)
33. Tsui and Mok (2024)
34. Mazana et al. (2024)</td>
</tr>
</table>

5.1 Theme 1 Teacher Preparedness and Perceptions in Blended Learning

Teacher preparedness and perception towards blended learning become critical areas of interest brought about by the pandemic era. As Fujita et al. (2023), Huang et al. (2023) and Erianjoni et al. (2023) have shown, mathematics teachers varied in their readiness across regions. Japanese elementary and junior high school teachers encountered barriers of lack of experience with digital tools and difficulties in creating interactive lessons when progressing to online teaching

(Fujita et al., 2023). In contrast, teachers in Shanghai's primary schools adapted more readily due to institutional initiatives, such as expert-designed video lessons and collaborative group experience (Huang et al., 2023). At Universitas Negeri Padang, teachers who had a long history of using online learning since 2013 showed readiness and sufficient knowledge (Erianjoni et al., 2023). These findings emphasize how institutional support and prior experience have a different effect on teacher preparedness for blended learning environments.

The attitudes of mathematics educators toward integrating technology in blended learning reflect both challenges and opportunities (Engelbrecht et al. 2023; Morton & Durandt, 2023; Li, 2023). According to Engelbrecht et al. (2023), the shift to emergency remote teaching changed how educators perceived technology for enabling collaboration and interactivity through tools using social media and digital platforms. Morton and Durandt (2023) additionally found that educators struggled to adapt to full online teaching, utilizing technology to enable active learning and self-regulation among students, and relying on digital tools to ease the adaptation to new teaching practices. Li (2023) proved that while Chinese primary mathematics teachers are positive towards technology integration, they still lack the knowledge to employ technology fully to improve teaching effectiveness. These studies emphasize the strong role that technology plays in shaping teacher attitudes and the need to develop strategies to improve teacher confidence and competence in using digital tools for blended learning.

Mathematics teachers who needed guidance during the pandemic were identified by Tunç-Pekkan et al. (2023), Callaghan et al. (2023), and Kunwar et al. (2023). Even though they gained a chance to plan, teach, reflect, and evaluate through an Online Laboratory School, Tunç-Pekkan et al. (2023) observed that the pre-service teachers in Turkey found teaching online very stressful, especially in evaluations. Conducting a similar analysis, Callaghan et al. (2023) found that South African teachers experienced challenges in adopting technology-enhanced teaching, especially in the design of learner-centered and interactive tasks using technology as a cognitive tool. According to Kunwar et al. (2023), Nepalese university mathematics teachers faced challenges such as limited access to resources, students' dependency, and difficulties teaching mathematics online due to its inherent complexity. The problems raised in these issues underscore the urgent requirement for professional development programs towards acquiring the technical and pedagogical skills of the teachers, especially those who facilitate the implementation of ICT in blended learning environments.

The adoption of blended learning poses significant challenges in the recruitment of teachers and adaptation in pedagogical aspects. As Glover and Stewart (2024) stated, recruiting high-quality mathematics and science teachers in Wales is a problematic process, particularly in rural areas and minority ethnic interests. They pointed out that flexible blended distance learning pedagogy makes it possible for teacher recruitment and training teachers to serve in rural schools. In the context of the abrupt shift to online teaching in Norwegian higher education, Radmehr and Goodchild (2023) highlighted challenges in adapting assessment practices and maintaining effective pedagogy in fully digital settings. According to Anwar et al. (2023), Indonesian secondary school mathematics teachers faced more challenges in public schools than in private schools. The limitations are in the learning tools, instructional methods, assessment processes, and time constraints. Based on these studies, blended learning holds the potential for addressing new teacher recruitment but also requires systemic support to overcome logistical and pedagogical barriers.

Therefore, the research shows that mathematics teachers generally perceive blended learning as a positive shift in teaching mathematics. Several challenges present themselves as barriers to the successful application of blended learning. These studies imply that it is possible to realistically augment the preparedness and perception of teachers toward blended learning in a supportive and adequate resource environment. This suggests that blended learning may improve teaching over time.

5.2 Theme 2 Technological Pedagogical Content Knowledge (TPACK) and Instructional Design in Blended Learning

Effective blended learning requires the integration of TPACK, which influences concrete teaching and learning practices. It helps teachers utilize technology with pedagogy and content to help create reflective and interactive contexts for students. Helsa et al. (2023) and Aini and Masrurotullaily (2024) show how TPACK influences teaching by equipping educators to design hybrid and online models conducive to computational and critical thinking yet this curricular change is indirect. It influences students only as long as teachers can forge relationships between technology and learning goals. For instance, Wischgoll and Prediger (2024) showed that better pedagogical content knowledge (PCK, a component of TPACK) allows teachers to better counteract student misconceptions and leads to better results in learning in general.

The strength associated with outcomes is often technological knowledge (TK) among teachers when comparing. For example, Aini and Masrurotullaily (2024) found pre-service teachers coped well with TK because they were exposed widely to digital tools during the pandemic. Nevertheless, integration of technological pedagogical knowledge (TPK) and technological content knowledge (TCK) with TK is still a challenge. Fitrah et al. (2024) found that experienced teachers in middle and high school settings generally outperformed in integrating TPACK because they were already familiar with the content and instructional strategy. Alternatively, Backfisch et al. (2024) highlighted that it was most difficult for pre-service and less experienced teachers to link technology to pedagogical approaches. These gaps in integration indicated that though teachers may be trained in technology, teacher TPACK needs to be developed more comprehensively to make complete integration.

Interventions that address these disparities in TPACK application are critical and tailored. Wischgoll and Prediger (2024) demonstrated that targeted strategies, in our case systematizing videos, specifically enhanced PCK for teachers with lower prior knowledge, showing that differentiated approaches matter. Backfisch et al. (2024) meanwhile observed that utility value interventions improved pre-service teachers' motivation and knowledge but did not immediately improve learning outcomes. The findings here indicate that TPACK's success depends on more than receiving the necessary technical proficiency. It also holds constant professional development and specially designed support for teaching to ensure that educators can employ blended learning suggestions in a way that works well for both teaching and learner participation.

The TPACK framework offers a foundational framework that facilitates instructors in planning, implementing, and evaluating these instructional strategies efficiently. Bautista and Valtoribio (2024) describe how, with TPACK, teachers can use flexible teaching and learning modalities to overcome barriers and personalize instruction. It provides a TPACK framework for how teachers should blend pedagogy and content through the integration of technology, such as flipped learning models where online tools like videos and even online platforms are used to strengthen teaching and learning. Additionally, Gopalan et al. (2024) noted that professional development in flipped teaching allows educators to develop the instructional design better, creating environments under TPACK to attain engaging, learner-centered environments. Together, these studies show how the use of TPACK supports the effectiveness of blended learning strategies in mathematics education and supports the way for innovation and adaption within mathematics education.

Alongside TPACK, blended learning strategies, such as flipped learning and station rotation models, are innovative instructional designs that significantly influence teachers and students. Papach et al. (2023) and Toivola et al. (2023) showed shifted capability of content delivery out of the class, where teachers can pay attention to interactive, student-centric activities in the class. Flipped learning provides opportunities for deeper conceptual understanding through self-regulated learning and individualized instruction to increase student engagement. Abdul Latif et al. (2024) also pointed out that the combination of manipulatives, group activities and digital tools, as considered by the station rotation model, allows for better student learning and better teacher facilitation. Nevertheless, in contrast to Kämpf and Stallmach (2024), who highlighted that spiral curricular designs are of paramount importance in blended learning, instructional strategies in the spiral curricular design of blended learning should have the ability to build on prior knowledge and seamlessly incorporate mathematics into the physics discipline.

However, the comparison in the impact of these models revealed flipped learning's application across diverse educational scenarios, such as preparing future mathematics teachers (Papach et al., 2023) and activating engagement and motivation (Toivola et al., 2023). For example, spiral-curricular blended learning models, such as those described by Kämpf and Stallmach (2024) provide domain-specific integration, which facilitates interdisciplinarity. Karaca and Akyuz (2024) pointed out that, although the essence of flipped learning is self-regulation and collaborative learning, the success of flipped learning in an online environment depends on carefully designed assessment strategies and participation norms. Similar to the findings in this paper, Matitaputty et al. (2024) highlighted how blended learning supports professional teacher education programs by enabling them to learn collaboratively and also develop specialized knowledge through digital distribution. These insights underscore the important of TPACK as a key factor influencing mathematics teachers' in blended learning.

5.3 Theme 3 Student Engagement, Learning Environment, and Outcomes in Blended Learning

Teachers' incorporation of cultural aspects, instructional approaches, and ICT tools improves motivation and learning in blended learning. This theme points to the use of the mathematics teaching and learning activity model, where cultural factors (Hofstede cultural framework) such as collectivism (group composition), fairness in rewards, and leadership among Tanzanian undergraduate students foster cooperation and motivation among students (Mazana et al., 2024). As a result, collectivism, which entails group work and community interdependence, was identified as the most significant cultural factor in teaching methodologies and students' cultural profiles. The research also established that the use of ICT tools such as learning management system and WhatsApp enhances collaborative learning, which acts as a moderator between culture and motivation. This synergy not only applies enjoyment to mathematics but also increases academic outcomes. The importance of culturally responsive and technology-integrated approaches to motivate students is emphasized.

Subsequently, Daher et al. (2023) built upon the conceptualization of task design, namely online learning for middle school mathematics and science teachers, on the interaction between the teachers as well as students and parents. As a result of incorporating a learning platform such as Zoom and Google Classroom, cognitive, social and psychological involvement is achieved. Engaging learners to actively respond and reflect on the designed tasks is effective in sustaining learners' motivation and interactions, especially when learning through virtual environments. In the same way, Millones-Liza et al. (2024) showed that adopting self-efficacy, perceived enjoyment, and ease of use is essential to enhancing students' satisfaction in a virtual mathematics learning environment. In line with such requirements, their study underlined the contingents based on the mutual construction of confidence and enjoyment with regard to the interactive and accessible tools that impact students' motivation.

According to Yudt et al. (2024), Fauzan et al. (2023), and Tsui and Mok (2024), it is crucial to understand better how both rural and urban student learning environments benefit from the blended learning strategies introduced in this article. Yudt et al. (2024) investigated the use of blended learning for pre-service elementary teachers, noting the benefit of modality flexibility that enables students to control learning time. This approach improves the attitude to mathematics learning for students in urban higher education settings by providing structure and student self-management. While the time for learning activities was sufficient, own and shared time, and limited instructor time availability hampered the development of instructional support for paraprofessionals. Learning environments could have supported students' academic achievement, indicating the need for more instructional support within urban settings.

Alternatively, Fauzan et al. (2023) focused on blended learning in the Indonesian rural context, which was characterized by language and resource differences. To deal with these challenges, the study employed culturally responsive practices such as translanguaging and trans-semiotizing in content and language integrated learning classrooms to capture learners' attention and foster subject content understanding. These methods enriched academia and the social development of children but were threatened by time as government-prescribed hybrid schedules. The results indicated that, although the structural design of the blended learning model is advantageous to learners from urban areas, learners from rural areas need culturally appropriate practices to minimize the contextual differences to ensure positive outcomes are achieved.

Building on these studies, Tsui and Mok (2024) investigated how COVID-19 (during and after the crisis) affected secondary schools by using the blended-learning environment. Based on their study, the authors increased awareness of technological difficulties, curriculum changes, and parental support as factors that affect performance. Young people in urban areas who had better access to technology in their studies were likely to benefit greatly from some of the changes in the curriculum compared to their rural counterparts who had major challenges in sustaining their engagement. Tsui and Mok (2024) indicated the importance of support infrastructures, including disciplined strategies to balance motivators, minimize distractions, and optimize academic performance in different environments.

Blended learning strategies significantly reshape learning environments and interactions between students and teacher. Liew et al. (2023) described such strategies, such as "You Talk" and "Resource Pool", that effectively improve academic outcomes, student satisfaction, and more engagement during online teaching and learning. Similarly, Wang et al. (2024) considered the change in traditional instruction to blended learning in Hong Kong secondary schools during and after the pandemic, focusing on the priorities in the field of curriculum adaptation, technology integration, and parenting support. Best practices were encouraging student to use technological tools with disciplined strategies to avoid distractions and, thus, optimize blended learning instruction. On this basis, Rueda-Gómez et al. (2024) pointed out five factors that mediate the successful of online platform among professors, namely obstacles, teacher contribution, student, reinforcement and platform.

Overall, the research suggested that blended learning success relies on tailoring strategies to urban and rural context, bridging cultural and technological gaps, and providing equal opportunities to learners and achieve beneficial learning. Moreover, learning environments in blended contexts have to be promoted in an innovative way using improvised tools and strategies with supportive systems to increase interaction and academic outcomes.

6. Discussion

Teacher readiness and perceptions influence blended learning in mathematics education, which requires institutional support, experience and systems. There are differences in readiness, particularly the starting points between areas with existing digital structures and those which transitioned to online instruction during crises. Those institutions that allow teachers to be exposed to blended learning tools and more collaborative professional settings can afford to adopt more (Chin et al., 2019). In contrast, they did not use digital tools regularly in their work. There are no clear guidelines leading to readiness assistance.

These differences underscore the importance of institutional planning in the area and prepare teachers for an analysis of the integration of technology into the respective teaching paradigms about blended learning (Aliyu et al., 2021; Ratnayake, 2020).

Perspective and professional support are as important as confidence and competency and, along with system resistance factors, are intertwined. While some could see the possibility of using technology to facilitate collaboration and student engagement, many fail to integrate or find the appropriate uses of technology to blend with their instructional plans, as the void of adequate technical and instructional literacy conditioner hinders them (Santamaría-Cárdaba et al., 2021; Wassie & Zergaw, 2019). Teacher professional development programs, even though crucial, often do not align with the unique needs of teachers in underserved areas or ease the burden of performance stress (Thurm & Barzel, 2020; Weinhandl et al., 2020). Blended learning success requires new training paradigms that do not merely add context relevance, experience continuity, and freedom from system-biased perspectives to pedagogical specifics. If these aspects are addressed systematically, then teachers will not only be presented with and ready to embrace such a blended learning approach in mathematics education.

Technology integration, TPACK, is important for the successful implementation of blended learning, although its acquisition and use are not adequately developed across different learning environments. TPACK strongly stands as a framework and helps teachers design and teach interactive instruction models, including blended and inverted learning models (Galanti et al., 2020; Rakes et al., 2022). However, the integration of TPACK into teaching practice depends on teachers' practice experience, professional development, and the institutional environment (Bueno et al., 2021). Despite that, the challenges is in balancing the integration of digital tools with effective pedagogy (Clark-Wilson et al., 2020; Kadirbayeva et al., 2022). Moreover, instructional design in blended learning, such as flipped classroom, supported by technology, fosters active participation with individuals students or the whole group (Gong et al., 2024; Ramadhani et al., 2019). Additionally, blended learning can improve teachers' TPACK for developing multimedia mathematics learning (Sintawati & Abdurrahman, 2020).

These results imply that TPACK and instructional design work together to enhance the influence of blended learning in mathematics classes.

Challenges in blended learning, such as motivational strategies, interaction, and infrastructural support, focus on student engagement, the learning environment, and academic outcomes, which are the main dimensions of blended learning (Graham & Halverson, 2023). Students' involvement in blended learning environments depends on the tasks and tools needed and the culture of the students (Xu et al., 2021). The results of the application of blended learning also entail the quality of interactions and flexibility of the forms and methods of individualized instruction. These interactions in an online environment are used to maintain active participation and parental cooperation and ensure continuity of activities and assessment (Indrapangastuti et al., 2021; Isnawan & Almazroei, 2023; Warren et al., 2021). However, the differential availability of technology based on the locale persists because not every place possesses the required technological infrastructure for teaching and learning tasks (Kundu et al., 2021).

The findings highlight critical factors influencing mathematics teachers' adoption of blended learning. Enhancing foundational professional development is essential to improve teacher readiness and digital competence, enabling effective integration of blended learning practices. Advanced professional development in technology integration is equally important for bridging gaps in TPACK frameworks and equipping teachers with innovative instructional strategies. Furthermore, student engagement and equitable access through motivational strategies, group work task designs, and addressing technological disparities ensure inclusive and impactful blended learning environments (Al-Ayed & Al-Tit, 2021). Together, these outcomes provide actionable insights for educators and policymakers to optimize blended learning in mathematics education.

7. Conclusion

This study has found the factors influencing mathematics teachers' blended learning, highlighting the three themes of teacher preparedness and perceptions; TPACK and instructional design; and student engagement, learning environment and outcomes. These factors are required to prepare mathematics teachers for blended learning. Relating motivation, interaction and alignment of blended learning tasks to student engagement and improved academic achievement has reinforced the role of blended learning.

Contextualized strategies that support cultural and linguistic differences ensure the provision of all learners' learning needs effectively, improving learners' participation and interactivity. Innovative technology resources and learning platforms offer interactivity to learners. However, the failure to close the technological, resource, and curriculum gap continues to pose significant challenges to the delivery of equity. Therefore, teachers need to be supported with professional development to ensure the effective implementation of blended learning, which must align with technical and pedagogical skills. The results of this study imply that blended learning models depend on the equal distribution of advantages and appropriate support for teachers and students. This review is limited to the context of mathematics education and includes only two search engines, WoS and Scopus, and papers published in the last two years.

Future research should explore effective professional development designs that include content knowledge upgrading and pedagogical technique training for different areas. Moreover, there is an opportunity to expand the use of TPACK frameworks by introducing innovative developments in blended learning and enlarging the application of artificial intelligence and adaptive learning platforms. Examining these areas will help enrich the existing knowledge about the possibilities of blended learning and impacts on mathematics education and other fields.

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