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PAPER

Blended Learning in Mathematics Teacher Education: A Systematic Review

Duong Huu Tong(✉), Bui Phuong Uyen, Lu Kim Ngan

Can Tho University, Can Tho City, Vietnam

dhtong@ctu.edu.vn

ABSTRACT

Blended learning is an active teaching approach widely applied in recent decades, especially in higher education. This study systematically reviews blended learning's applications in mathematics teacher education based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This study aims to understand the potential of blended learning for various mathematical topics, the common blended learning models, and the benefits and challenges this teaching approach presents for educational stakeholders. Accordingly, 25 studies from the Scopus database are analyzed. The study shows that many studies were conducted between 2019 and 2022, focusing on a few developing countries. In addition, blended learning is extensively used in teaching most mathematics subtopics, especially in courses on teaching methods, with the widespread use of three models: the flipped model, the mixed model, and the online practicing model. Based on this study's assessment, blended learning has a positive impact on the development of knowledge, skills, and attitudes among preservice teachers. However, it also presents lecturers and prospective teachers with various challenges related to technological infrastructure, teaching materials, digital and professional competence, and students' knowledge and engagement. The study's results provide an overview of the application of blended learning in mathematics teacher education and support certain future recommendations for new research directions.

KEYWORDS

blended learning, mathematics teacher education, systematic review

1 INTRODUCTION

The outbreak of the global COVID-19 pandemic has created many challenge in education, forcing teachers and learners to limit face-to-face learning in order to ensure compliance with disease prevention requirements [1]. In this context, blended learning is considered an effective teaching approach suitable for practical requirements. Introduced in the early 2000s, blended learning has been widely

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recognized as an effective method for overcoming many limitations of traditional teaching methods for over a decade [2], becoming a teaching trend that is applied more and more at the university level, in particular [3]. However, it was not until the COVID-19 epidemic that blended learning became a global trend and received the attention of educators. Training mathematics teachers at the undergraduate and graduate levels is important in ensuring the quality of mathematics education in general. Equipping mathematics teachers with sufficient theoretical and practical knowledge is crucial for developing teaching quality and boosting teachers' confidence. Therefore, blended learning, with its advantages of providing continuous, flexible, and reasonable time learning methods, has been applied in the training of mathematics teachers in many universities.

The development of information technology (IT) and practical needs has inspired research on applying blended learning in education. As a result, numerous studies have been conducted in various fields, ranging from primary schools to universities, with diverse purposes, research methods, and mixed research results. Many aspects of the application of blended learning in mathematics teacher education have been explored. A systematic review is appropriate given the wealth of published studies on blended learning in mathematics teacher education, as the results of various relevant studies differ in many aspects [4]. Although several systematic review studies on blended learning have been carried out [2] [5]–[10], there has not been one that specifically assesses blended learning models suitable for use in mathematics teacher education, along with the benefits and challenges of applying this teaching approach. Therefore, it is essential to carry out a systematic review study on blended learning in the education of mathematics teachers at the university level.

This study assesses the blended learning models commonly used in mathematics teachers' education and clarifies the benefits and challenges this teaching approach brings educators and preservice mathematics teachers.

1.1 Blended learning

Definition. Bliuc et al. (2007, as cited in [11]) describe blended learning as learning activities that synthesize face-to-face and technology interactions between students, teachers, and learning materials. Similarly, Castro (2019) believes blended learning integrates traditional teaching, face-to-face in-class instruction, and online learning [12]. Thus, the definitions of blended learning all refer to a common component: integrating different teaching methods. These methods combine two forms of teaching: face-to-face and computer-aided learning. Accordingly, Alammary (2014, 2019) defines blended learning as courses that (1) thoughtfully integrate different instructional methods, such as lectures, discussion groups, and self-paced activity, and (2) contain both face-to-face and computer-mediated portions [2] [11].

Models. Blended learning models are categorized by the type of interaction they create. Accordingly, blended learning includes five main models [11].

(1) Face-to-face instructor-led: Students learn directly, with teacher instruction and little interaction.
(2) Face-to-face collaboration: A teaching approach that encourages students to work together in the classroom, such as in group discussions.
(3) Online instructor-led: Teachers teach online, control learning progress, and set interactions.

(4) Online collaboration: Students are encouraged to work in online groups, as in online discussions.
(5) Online self-paced: Students are allowed to learn autonomously, at their own pace, and to be proactive about time and place, such as by reading online or watching videos.

A systematic review study by Ashraf et al. (2021) shows that eight different models have been applied in many blended learning studies, including the flipped model, station rotation model, flex model, mixed model, supplemental model, online practicing model, self-blend model, and enriched virtual model [5]. Meanwhile, Alammary's (2019) research shows that the commonly applied blended learning models include flipped, mixed, flex, supplemental, and online practicing models [2]. This study focuses on five blended learning models described in [2].

The flipped model is one in which students learn theoretical content online and class time is used for problem-solving. The mixed model allows students to learn theory and practice face-to-face and online. A flex model is an online form of theoretical and practical learning, but it requires students to periodically participate in face-to-face learning to check learning progress and provide feedback to the teacher. The supplemental is a face-to-face learning model for theory and practice; online learning is added to enhance student learning engagement. The online-practicing model places online practice and problem-solving at its core, and students can get immediate feedback on their answers. Theoretical content can be learned through lectures or online self-study materials [2] [5]. The flipped classroom is commonly used in universities because this model can easily be integrated into existing teaching and learning systems without restructuring the faculty's organizational structure [7].

Design principles. Aside from choosing an appropriate blended learning model, many researchers advocate that designing a teaching and learning environment with blended learning must meet certain principles. Osguthorpe and Graham (2003, as cited in [13]) proposed six possible goals for designing blended learning environments:

(1) Improving the pedagogical richness
(2) Facilitating access to knowledge
(3) Supporting social interaction
(4) Developing learners' agency
(5) Achieving cost-effectiveness
(6) Enabling ease of revision

In addition, Boelens et al. (2017) summarize four main challenges to the design of blended learning environments, including (1) incorporating flexibility—learners have some control over when, where, and how they learn [14], (2) encouraging interaction, (3) assisting students in their learning processes, and (4) fostering a positive learning environment [8].

Advantages. In general, blended learning entails both face-to-face and online components. According to [15], by integrating online learning into the system, blended learning expands the learning environment into a virtual world where the limitations of traditional teaching can be overcome. Through the online component, it becomes easier to discern student needs and combine them with the social aspects of the real classroom to form a solid learning system [15] [16]. For mathematics education, online components fit lecturers' time constraints and enhance learners' opportunities to explore and visualize mathematical concepts and ideas. In addition, face-to-face

components enable concurrent communication and knowledge construction in real-world contexts [17]. This mutual relationship was also confirmed by [13].

Many studies have shown that blended learning brings numerous benefits to learners' learning, such as ensuring theoretical learning with flexibility concerning time, enhancing self-assessment ability, accountability, learning engagement, motivation, and interest in learning [18] [19], creative and critical thinking, the ability to collaborate, work in groups, and improve academic performance. At the same time, teachers can better interact with learners and deploy a variety of ideas in problem-solving. Reviews by [2] [7] [9] demonstrate this.

A survey by [20] showed that students responded positively to applying blended learning in different subjects. First, better access to learning materials and personalized learning opportunities improve workload distribution and make learning more relevant to learners' needs. The fundamental ideas of smart education are adhered to in this. Second, blended learning significantly reduces the pressure of studying learning materials at the review stage for final assessments.

In particular, several studies on the application of blended learning in preservice teacher education indicate that blended learning has a positive impact on subject results and fosters positive learning attitudes among teacher students [6], and it provides diverse learning materials, opportunities for interaction, quick feedback, and flexibility in both self-directed learning and controlling learning progress [6] [13] [21].

Challenges. Along with the benefits of the teaching and learning process, blended learning poses many challenges for lecturers. These challenges can be viewed from the distinctive perspectives of educational institutions, lecturers, and students [10].

From the perspective of educational institutions, Pozo et al. (2020) argue that one of the factors that make it hard to apply blended learning is the lack of training of the teaching staff on aspects related to advanced teaching methods and technology application information, along with the investment required to implement this teaching approach [22] [23]. Learners are not familiar with blended learning, which is also a problem. Research [24] [25] showed that limitations in Internet access and facilities, connection errors, a lack of teaching materials, and the compatibility of the curriculum with blended learning are among the challenges of this teaching approach.

Another challenge to applying blended learning is the role of the lecturers. When applying blended learning, in which synchronous or recorded lectures replace face-to-face lectures, the teacher's lectures still play a major role in shaping learners' knowledge. If lecturers lack training and expertise in online instruction, this creates numerous problems [23] [24] [26]. On the other hand, the anxiety of in-service and preservice teachers towards information and communications technology (ICT) use is a further challenge to this teaching approach [24] [25]. In addition, the limitations on teaching time can lead to reductions in group discussion activities, increasing the role of the teacher and thus reducing the role of the learner in student-centered learning and self-directed learning. Limited teaching time limits active learning activities such as project-based learning, problem-based learning, and other alternative assessment forms. These constraints contradict educators' assumptions about blended learning [15].

On the other hand, the assessment also poses many challenges for blended learning. Although online communication platforms can facilitate learner-learner interactions roughly equivalent to face-to-face learning, routine assessment by the teacher has significant limitations. This results in teachers and learners being unfamiliar with online assessment forms and unable to accurately judge learners' honesty in completing assignments without direct supervision [24]. From a learner's perspective, self-regulation, procrastination behavior, lack of online help-seeking, technological literacy and competency, student isolation, technical sufficiency, and technological complexity are significant challenges for students in a blended learning course [10].

1.2 Mathematics teacher education

One of the primary goals of mathematics teacher education is to develop teachers' professional competence, which spans a continuum of dispositions, including cognitions and affect-motivations as well as situation-specific skills and performance (Blömeke et al., 2015 [27]). To achieve this goal and to improve the quality of mathematics teaching, it is necessary to promote professional development for preservice and in-service mathematics [15] [26]. According to Suzuka et al. (2009), regarding mathematical knowledge, courses need to help preservice teachers clarify and develop a flexible understanding of mathematical ideas, stimulate learners to expose errors caused by a subjective understanding of mathematical ideas, allow learners to connect mathematical ideas, provide a variety of mathematical representations and solutions, and give them opportunities to engage in mathematical practice [15].

To ensure a high quality of education and continuous learning, according to [15] [20] [28], blended learning, with the support of technology and the internet, makes the design of courses more effective, overcoming limitations due to a large number of students or other objective conditions that might impede direct learning. Accordingly, [17] designed a professional development course in teaching mathematics based on the application of blended learning with a high degree of self-directed, autonomous online learning to develop mathematical knowledge for teaching. The research results demonstrate the feasibility of building an online learning environment to develop mathematical knowledge for teaching.

1.3 Research objectives and questions

This review aims to determine the effectiveness of blended learning in various preservice mathematics teacher education courses and the challenges involved. The following research questions define the focus of this review.

RQ1: What are the descriptive characteristics of the studies that comprise the systematic review (such as years of publication and the nations where they were conducted)?
RQ2: What testing methods have been used to assess the effectiveness of blended learning in mathematics teacher education?
RQ3: What are the main advantages of blended learning in mathematics teacher education?
RQ4: What are the challenges of using blended learning in mathematics teacher education?

The study examines several recent, pertinent studies to answer these research questions.

2 METHODOLOGY

2.1 Design

We decided to conduct a systematic literature review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to provide a comprehensive picture of the existing research on blended learning in mathematics teacher education [29] [30]. The goal is to examine the content of the

25 articles selected to answer the research questions. Figure 1 represents the protocols for conducting the systematic review.

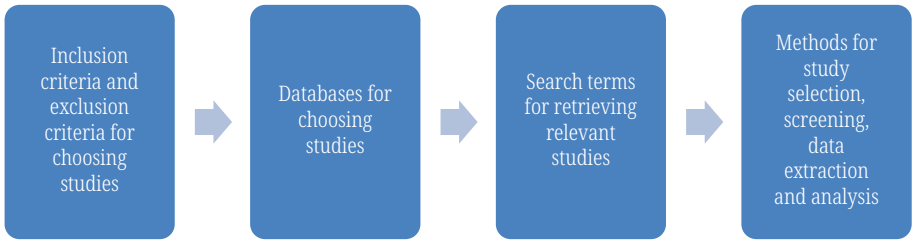

Fig. 1. Protocols for study selection

2.2 Search strategy for locating relevant studies

We used a range of electronic databases to search for studies on the application of blended learning in higher education mathematics teachers, including Scopus, ScienceDirect, Taylor & Francis Online, Mendeley, Google Scholar, and ERIC. These databases were chosen for their online accessibility and the wide range of education-related research they offer. However, to narrow down the scope of research, we cross-checked the studies found in these databases through the Scopus resource system, and selected works that are included in the Scopus system's catalog.

To search for studies relevant to the objective of this study, the search terms used on the databases included 'blend learning' + 'mathematics teacher education', 'blend learning' + 'preservice mathematics teachers', 'blended learning' + 'prospective mathematics teachers', 'hybrid learning' + 'mathematics teacher education', 'hybrid learning' + 'preservice mathematics teachers', 'hybrid learning' + 'prospective mathematics', 'flipped classroom + 'mathematics teacher education', 'flipped classroom' + 'mathematics preservice teachers', and 'flipped classroom' + 'prospective mathematics teachers'.

To avoid bias in finding relevant research, the research team members independently conducted searches the databases using the predetemined search terms and they selected and excluded studies based on screenings the full texts and applying previously agreed-upon inclusion/exclusion criteria. The studies selected obtained informed consent from all researchers after through discussions.

2.3 Criteria for including and excluding studies from the review

The studies selected are experimental or survey studies with various research methods. A selected study needed to satisfy all of the following inclusion criteria:

(IC1) Journal articles
(IC2) Written in English
(IC3) The study was published during 2012–2022; the last study search was conducted in September 2022
(IC4) Research is carried out as an experimental study or a survey
(IC5) Research related to the application of blended learning in teaching mathematics pedagogical students
(IC6) Research using two components face-to-face component and online component

Studies were excluded if one or more of the exclusion criteria below were met:

(EC1) Other forms of publication are not journaled articles
(EC2) Written in a language other than English
(EC3) The study was published before 2012
(EC4) The study is not an experimental or survey study
(EC5) The study was not conducted for students of mathematics pedagogy
(EC6) Research only examined face-to-face components or online components
(EC7) Duplicate articles

2.4 Data extraction

The initial search for articles yielded a total of 544 related articles. Using the End-Note reference management software, we created a database of these articles, which included titles, abstracts, and full texts. After removing duplicate articles, the number of remaining articles was redued to 247. Subsequently, through title and abstract screening, 192 articles were excluded from consideration for the next phase. The remaining articles were carefully reviewed through full-article reviews. Once 30 articles were excluded because they did not meet the inclusion criteria. Finally, 25 relevant articles were retained for analysis in this systematic review. The process of selecting articles, as recommended by PRISMA, is illustrateded in Figure 2.

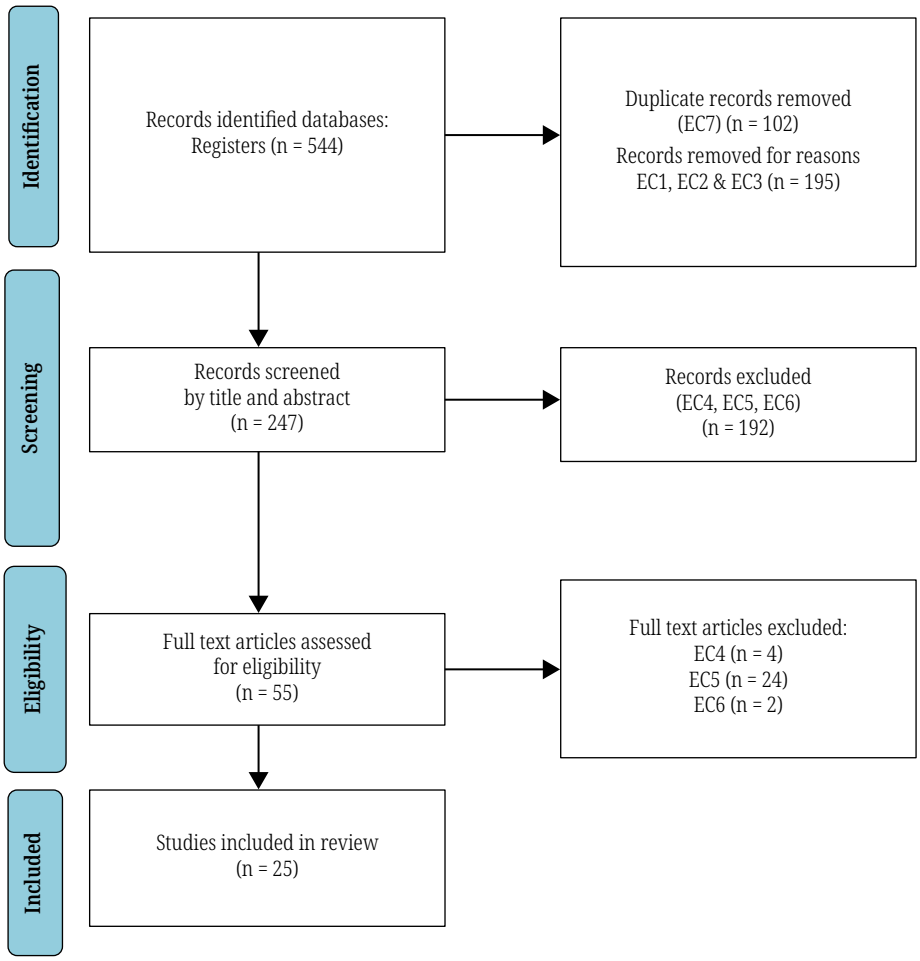

Fig. 2. PRISMA flow diagram

3 RESULTS AND DISCUSSION

3.1 Characteristics of the studies

RQ1: What are the descriptive characteristics of the studies that comprise the systematic review (such as years of publication and the nations where they were conducted)?

Table 1. Distribution of articles by year of publication

Year of Publication	Paper ID	f	%
2012	[31]	1	4.00
2013		0	0.00
2014		0	0.00
2015	[32], [33]	2	8.00
2016	[34]	1	4.00
2017		0	0.00
2018	[35]–[37]	3	12.00
2019	[38], [39]	2	8.00
2020	[40]–[46]	7	28.00
2021	[47]–[50]	4	16.00
2022	[51]–[55]	5	20.00

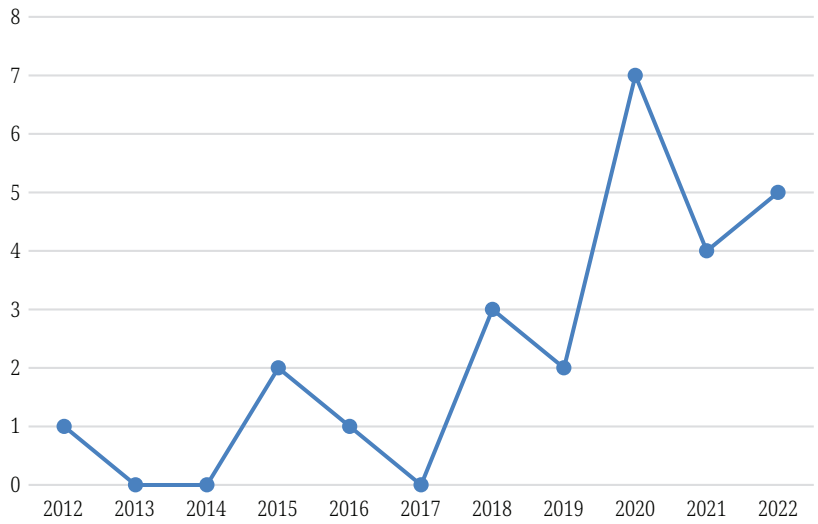

Fig. 3. Year of publication diagram

Table 1 and Figure 3 present the distribution of studies by publication year. From 2019 until the present, there has been a relatively significant increase in the number of studies on applying blended learning in mathematics teacher education. In particular, the year 2020 witnessed a profound growth in the number of studies, with seven articles published. The surge in research during 2020 can be attributed to the COVID-19 pandemic outbreak, which disrupted students' educational activities. The pandemic compelled educational institutions to adopt blended learning in their teaching practices, leading to increased research efforts to understand

various theoretical and practical aspects of blended learning to meet instructional needs effectively.

Table 2. Distribution of articles by country

Countries	Paper ID	f	%
Brazil	[52]	1	4.00
Canada	[41]	1	4.00
Ghana	[32]	1	4.00
Indonesia	[35], [38], [39], [40], [43], [46], [47], [49], [53], [54]	10	40.00
Korea	[34], [36]	2	8.00
Palestine	[48]	1	4.00
South Africa	[42], [33], [45]	3	12.00
Spain	[31], [37]	2	8.00
Turkey	[51], [44]	2	8.00
Ukraine	[50]	1	4.00
Zimbabwe	[55]	1	4.00

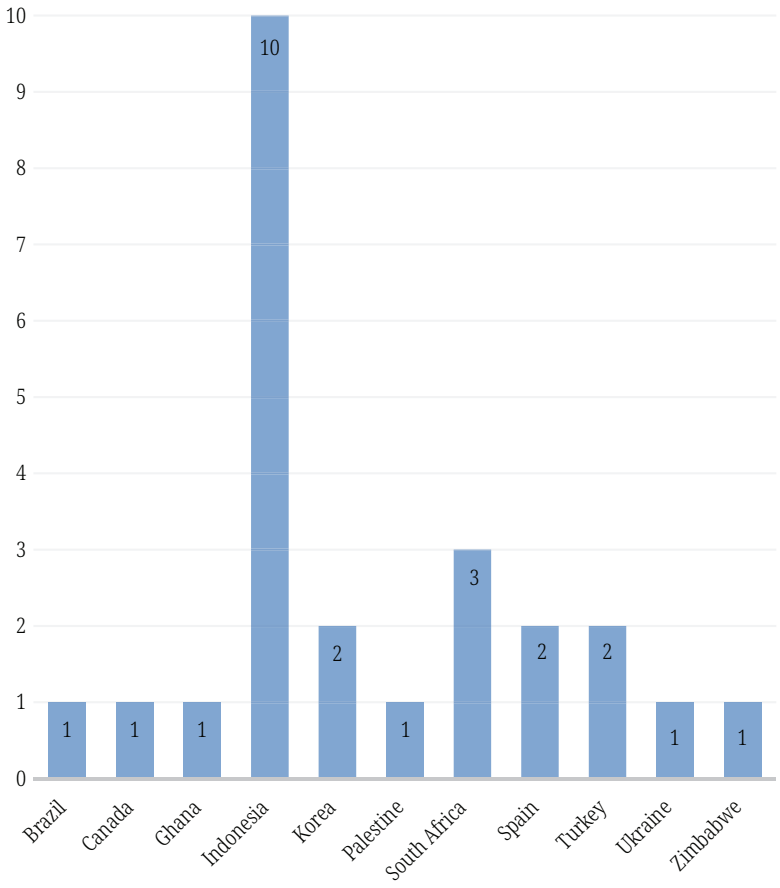

Fig. 4. Distribution of articles by country

The authors' affiliation countries shown in Table 2 and Figure 4 show that Indonesia has the highest number of publications (10 studies), published between 2019 and 2022. This can be explained by the requirement for practical standards when implementing

social distancing starting in 2019 to stop the spread of COVID-19. In addition, developing countries' efforts in the Fourth Industrial Revolution era are demonstrated most clearly in applying information technology in socio-economic fields, including education. This practice motivates educators and administrators to bring technology into education through face-to-face and online learning in teacher training. In light of this, new teachers may implement blended learning in their classes. As a result, there has been growth in research that facilitates the application of blended learning in the education of mathematics teachers in these countries, especially in Asia [56].

Notably, the studies were carried out in almost all regions of the world. However, the number of studies is relatively small (less than three). Numerous factors could cause this, but adequate facilities and educational resources might be the main ones. In this case, the cooperation and support of educational management units in terms of facilities and professional training of teachers in ICTs and blended learning are crucial.

Table 3. Distribution of articles by mathematics subtopics

Mathematics Subtopics	Paper ID	f	%
Algebra	[41], [52]	2	8.00
Arithmetic	[41], [51]	2	8.00
Calculus	[33], [47]	2	8.00
Geometry	[49], [54]	2	8.00
Probability & Statistics	[41], [43], [44]	3	12.00
Teaching Methods	[32], [48], [50], [55]	4	16.00
Others	[31], [34], [35], [36], [37], [38], [39] [40], [42], [45], [46], [53]	12	48.00

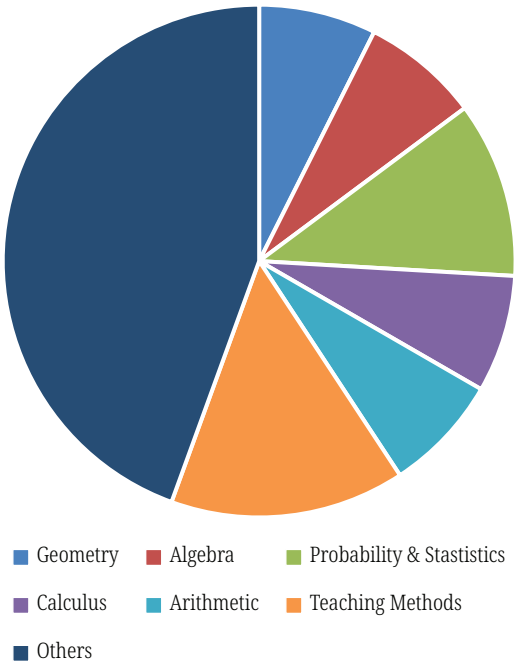

Fig. 5. Distribution of articles by mathematics subtopics

Regarding mathematics subtopics, blended learning is widely used in teaching various areas of mathematics education (see Table 3 and Figure 5). The fields of teaching methods and Probability and Statistics dominate, accounting for 16% and 12% of the total research, respectively. Additionally, research has been conducted in the fields

of Geometry, Algebra, Calculus, Arithmetic, and other fields. Given that these studies were carried out for the undergraduate level in training mathematics teachers, it is evident that increasing the application of blended learning in teaching modules on teaching methods is practical and effective. This approach helps meet the professional requirements of students when practicing teaching. Furthermore, blended learning is also applied in various areas of mathematics, allowing students to observe and experience its application in teaching mathematical topics during their practice teaching. By designing lessons, observing how a class is organized, checking and evaluating lecturers, and with the role of learners who have authentic learning experiences in blended learning lessons, mathematics preservice teachers can acquire knowledge of teaching organization, as well as analyze and compare to augment their own experience.

Table 4. Blended learning models

Model	Paper ID	f	%
Flipped model	[34], [36], [37], [39], [42], [44], [54]	7	28.00
Mixed model	[43], [46], [48], [49], [50], [52]	6	24.00
Supplemental model	[41]	1	4.00
Online practicing model	[31], [32], [33], [38], [51], [55]	6	24.00
Blended learning (not mentioning particular models)	[35], [40], [45], [47], [53]	5	20.00

Table 4 shows the blended learning models used in the studies. Most studies refer to the specific model used (20 studies), and some consider the blended learning approach in general (five studies). In cases where the authors did not mention the model they used, this was determined based on comparing their methods of organizing blended learning with [2] [11] model descriptions. Accordingly, four different models were used among the selected studies: flipped, mixed, supplemental, and online practice.

Based on the assessments, the flipped model is the most used (seven studies, accounting for 28%). This model allows learners to engage in online theoretical learning and spend class time problem-solving and discussing the content [2] [11] [57]. The mixed and online practicing models are the other significantly more widely adopted models, with six combined studies of 48%. In the mixed model, learners participate in theoretical and practical learning in both face-to-face and online formats. Unlike the online practicing model, the mixed model involves students conducting practice activities on specialized online learning platforms [2] [5]. With the mixed model's characteristics as described above and given that the relevant studies were published between 2019 and 2022, it can be said that the mixed model is appropriate for use during the study period that the COVID-19 epidemic interrupted.

Finally, it is worth noting that among the studies analyzed, only one study applied the supplemental model, which focuses predominantly on theoretical and practical face-to-face learning and relegates the online element to the status of an auxiliary activity [2]. In addition, Tables 3 and 4 show that each mathematical subtopic can be effectively taught using various blended learning models. This demonstrates the flexibility and feasibility of these models in teaching across a broad range of the mathematics teacher education curriculum.

3.2 Blended learning effectiveness testing methods

RQ2: What research methods have been used to assess the effectiveness of blended learning in mathematics teacher education?

Table 5. Distribution of articles by research methods

Methods	Paper ID	f	%
Quantitative	[38], [47], [50]	3	12.00
Qualitative	[31], [34], [35], [36], [41], [42], [43], [44], [52], [55]	10	40.00
Mixed methods	[32], [33], [37], [39], [40], [45], [46], [48], [49], [51], [53], [54]	12	48.00

Most of the selected studies on applying blended learning to the training of mathematics preservice teachers used mixed methods (12 studies, accounting for a total of 48%) to answer research questions. Aside from this, 40% of the studies use qualitative methods (10 studies), and the quantity of quantitative methods accounts for only 12% (three studies); see Table 5. With the above ratio, it can be seen that two qualitative and quantitative methods are used with almost equal frequency in these studies, where qualitative methods predominated. This phenomenon is explained below.

The 25 selected studies were conducted through various research designs, including surveys, case studies, quasi-experimental studies, and experimental studies. In some cases, studies used more than one research design. Only 2 out of the 25 studies were conducted in survey form (accounting for a total of 8%); four studies conducted case studies (16%), another four conducted quasi-experimental studies (16%), and 17 studies (68%) conducted experimental studies (see Table 6). In all experimental and survey studies, the subjects were preservice mathematics teachers (including students and graduate students), with sample sizes ranging from 7 to 315 participants (see Appendix).

Table 6. Distribution of articles by research designs

Designs	Paper ID	f	%
Case study	[41], [43], [51], [55]	4	16.00
Experimental	[31], [32], [33], [34], [35], [36], [39], [40], [44], [46], [48], [50], [51], [52], [53], [54], [55]	17	68.00
Quasi-experimental	[37], [38], [47], [49]	4	16.00
Survey	[40], [45]	2	8.00

Table 7. Distribution of articles by evaluation instruments

Instruments	Paper ID	f	%
Test	[33], [39], [43], [46], [47], [49], [51], [54]	8	32.00
Questionnaire	[32], [37], [40], [45], [46], [49]	6	24.00
Interview	[33], [34], [36], [42], [43], [44], [45], [48], [49], [51], [52], [54], [55]	13	42.00
Observation	[31], [32], [35], [38], [39], [41], [42], [46], [52], [55]	10	40.00
Self-reflective journals	[34], [36], [39], [54]	4	16.00
Others	Lesson plan: [32], Course plan: [51], Footage: [52], Final products: [31], [41], Reflections: [48], The average success rate in the subjects: [50]	7	28.00

Table 7 shows the evaluation instruments used in the selected studies. The five main evaluation instruments used were interviews (13 studies, accounting for 42%), observation (10 studies, accounting for 40%), tests (eight studies, accounting for 32%), questionnaires (six studies, accounting for 24%), self-reflective journals (for research, accounting for 16%), and some other tools equivalent to final products

(seven studies, accounting for a total of 28%). The implementation of blended learning in the classroom, its impact on students' knowledge acquisition, skills, and critical thinking was assessed using tests, self-reflective journals, and output products. Students' attitudes, engagement, and challenges with blended learning were primarily examined using interviews, questionnaires, and observations (see Appendix). The significant number of studies using tools such as interviews, questionnaires, and observation explains why qualitative data processing and analysis methods account for a high percentage of the total number of selected studies.

3.3 Advantages of blended learning in mathematics teacher education

RQ3: What are the main advantages of blended learning in mathematics teacher education?

Table 8. Main advantages of blended learning in mathematics teacher education

Advantages	Paper ID
Knowledge and academic performance	
Pedagogical knowledge	[38], [52]
Content knowledge	[33] (not meet), [38], [41], [49], [52], [53]
Technological knowledge	[38], [51], [52]
Technological pedagogical knowledge	[38], [52]
Technological content knowledge	[38], [52]
Academic performance	[37], [40], [45], [50]
Cognitive skills and soft skills	
Higher order thinking	[34], [35], [46], [47]
Pedagogical skills	[31]
Technology integration skills	[32], [38], [51], [52]
Research skills	[51]
Independence learning	[39]
Social interaction/communication	[35], [41], [42], [48]
Cooperation/Collaboration	[39], [42], [44], [54]
Attitudes	
Engagement	[44], [48]
Motivation	[36], [38], [49]
Satisfaction	[35]
Positive learning attitude	[35], [36], [37], [49], [51]
Self-directed learning readiness	[40]
Self-efficacy	[34], [40], [51], [54]
Self-regulation	[44]
Awareness of technology integration	[45], [51], [52]
Learning awareness	[39], [54]

(Continued)

Table 8. Main advantages of blended learning in mathematics teacher education *(Continued)*

Advantages	Paper ID
Others	
Time-saving	[42], [51]
Reasonable cost of tools	[55]

Table 8 lists the various advantages cited in the 25 selected studies. Most studies refer to developing students' thinking and soft skills through blended learning (15 studies). Among them, four studies demonstratess the development of higher-order thinking in mathematics preservice teachers after taking courses with a combination of face-to-face and online learning [34] [35] [46] [47]. Five studies show the effectiveness of blended learning in developing students' technology application skills (four studies), pedagogical skills (one study), and research skills (one study). In addition, through self-study activities, online interactions, and discussions, mathematics preservice teachers participating in studies have reported improvements in independent learning skills (one study), interaction and communication skills (four studies), and teamwork skills (four studies).

Aside from the above, the positive effects of blended learning on students' attitudes were also clarified in 15 studies. In particular, many studies show that students with more positive learning attitudes [35] [36] [37] [49] [51] are motivated to learn [36] [38] [49], actively engaged in learning [44] [48], and satisfied with the course [37]. Moreover, participating in courses organized according to the blended learning method has stimulated self-directed learning readiness [40], self-efficacy [34] [40] [51] [54], self-regulation [44], as well as learning and technology integrating awareness [39] [45] [51] [52] [54] among mathematics preservice teachers.

Regarding knowledge, 12 studies mention the benefits of blended learning for forming professional knowledge and learning outcomes for mathematics pedagogical students. Five of these studies show that students are, to a greater extent, endowed with the content knowledge, or mathematical knowledge, used in teaching [38] [41] [49] [52] [53]. A study [33] concluded that the impact was insignificant. Aside from this, two studies show that students can accumulate pedagogical knowledge [38] [52]. More specifically, in terms of technological knowledge, the application of blended learning in subjects for preservice mathematics teachers is mentioned in some studies as an effective tool for developing technological knowledge [38] [51] [52], technological pedagogical knowledge, and technological content knowledge [38] [52]. On the other hand, three studies have tested the progress in academic performance of mathematics pedagogical students after the experimental learning process with blended learning [37] [40] [45] [50].

In addition to the benefits of developing mathematics pedagogical students' knowledge, skills, and attitudes, three studies have confirmed the time and cost benefits of blended learning in teaching. Of these, studies by [42] and [51] suggest that applying blended learning saves students time in class; thus, students can spend more time learning theory and practicing self-study. Aside from this, the study mentioned that the reasonable cost of studying, thanks to the free support of many online learning platforms and low Internet charges, are benefits [55].

3.4 Challenges of using blended learning

RQ4: What are the challenges of using blended learning in mathematics teacher education?

Table 9. Challenges of blended learning in mathematics teacher education

Challenges	Paper ID
Technological challenges	
Infrastructure	[55]
Technical problems	[39], [44], [54], [55]
Tools selection	[32], [54]
Language (of technological tools)	[45]
Material challenges	
Resources	[32], [42]
Course content quality	[32]
Lesson plans/activities	[51]
Questions	[51]
Course preparation time	[39], [54], [55]
Time distribution	[51], [55]
Assessment	[55]
Competency challenges	
ICT skills	[32], [39], [54]
Dependence on the lecturer's professional development	[42]
Students engagement	[36], [55]
Knowledge transfer	[33], [55]

Along with the many benefits mentioned above, applying blended learning in mathematics teacher education poses several challenges too for lecturers and teacher students. Table 9 shows the challenges mentioned in 10 of the 25 selected studies.

Challenges related to technology factors (six studies) include inadequate facilities, such as computer equipment and Internet connection for lecturers and students (one study; [55]). In addition, technical issues, such as the lack of detective services and devices that support the online learning process, were mentioned in four studies [39] [44] [54] [55]. Furthermore, the teaching organizer's choice of the right tools [32] [54], the language used in the online teaching and learning platforms also pose significant obstacles, especially for lecturers and students in countries where English is not students'/teachers' first language [45]. These problems are no small challenges for many universities, especially in areas where socio-economic conditions cannot ensure adequate technological facilities for teaching. Therefore, investment in developing facilities in universities should be a priority. In addition, it is necessary to conduct studies on the development or application of tools that support blended learning and clarify the operation methods, advantages, and disadvantages of those tools. Choosing the appropriate tools for various educational objectives and environments will be possible while overcoming technical language or technique constraints. On the other hand, mathematics preservice teachers must actively learn different tools and improve their ability to use tools and their facility with foreign languages to meet the needs of applying technology and techniques in teaching with blended learning.

In addition to the features mentioned above of blended learning technology, studies also demonstrate teaching and learning materials issues. Studies by [32] and [42] mention the lack of material resources regarding tools and explain how the blended learning organization affects teachers' ability and confidence in applying blended learning. Research by [32] and [51] addresses the challenges of ensuring course content quality, preparing lesson plans and activities, and designing appropriate questions to apply blended learning effectively. According to these studies, lecturers may encounter difficulties in designing teaching content, learning activities, and questions to match the blended learning model used and online learning platforms; in addition, they must ensure that these questions are appropriate to the learner's level to help learners make connections between existing and new knowledge [32]. Moreover, the time factor also poses challenges for lecturers in teaching organizations with blended learning; there are three studies mentioning course preparation time [39] [54] [55], and two studies mentioning the time distribution between and within different components of blended learning [51] [55]. Studies are concerned that lecturers have to spend much time preparing lessons, as well as requiring a reasonable allocation of time between the face-to-face component and the online component, as well as the distribution of time between activities of dynamics in each component—all of which can drastically increase workload and affect teaching effectiveness. In addition, one study shows that assessment is a noticeable problem when applying blended learning [55]. Specifically, mathematics preservice teachers found it difficult to assess learners' progress in both online teaching and learning. Due to the limitations of continuous formative assessment, proximity and eye contact, teachers cannot determine students' needs or abilities to acquire knowledge, affecting teachers' lesson plan preparation [55].

Meeting the capacity requirements of learners and lecturers is a particularly important challenge for the effectiveness of blended learning. Firstly, three studies address the capacity of both lecturers and learners to apply ICTs [32] [39] [51]. The use and design of lectures, testing, and assessment on online platforms require teachers to be fully equipped with knowledge and skills to use as tools to support the teaching process. In addition, learners also need to have basic skills in applying ICTs to study online, practice, exercise, participate in online discussions, and search for other online learning materials. Second, according to [42], the effectiveness of blended learning depends on the teacher's professional qualifications and is also considered a challenge. This study suggests that teachers need to develop appropriate expertise to teach in different contexts and accommodate differences in learners' levels. In addition, student engagement is mentioned in two studies, one by [36] and another by [55]; students' knowledge transfer abilities, as mentioned in studies by [33] and [55], are also important issues. These studies indicate that the lack of teacher-student interaction and the many instances of learning disruption during online learning at home affect the engagement of mathematics preservice teachers. In addition, students said that during practice, they have difficulty transforming knowledge from learned knowledge into teaching knowledge or converting between representations of the same mathematical knowledge [33] [55].

4 DISCUSSION

The first research question investigates the descriptive characteristics of the selected studies regarding the year of publication, the country of publication, the

mathematical topics taught during the impact, and the blended learning model applied to teach that topic. The analysis revealed a sharp rise in studies on the application of blended learning in mathematics education starting in 2019 and reaching a peak in 2022. Consequently, it can be said that there is a high demand for online education right now. Dealing with the COVID-19 epidemic has stimulated the interest of educators in blended learning. Due to this, empirical studies or actual surveys are now required to shed light on the practical implications of implementing blended learning models, their efficacy, and their challenges when instructing mathematics to preservice teachers. Besides, this is mentioned in studies [2] and [24]. The first research question also addresses the geographical distribution of the countries conducting these studies. According to the results, these studies were conducted in many countries and regions, with Indonesia being the most popular reviewed study. This result is consistent with the contention of [56] that studies on blended learning are carried out in many developing countries in Asia.

Regarding the application of blended learning in teaching various mathematical topics, the research data shows that blended learning is applied in most mathematical subjects, especially in teaching methods. For mathematics pedagogy, developing students' knowledge and skills in teaching methods is essential for future teaching quality [26]. Regarding the blended learning models used in the studies, with the advantages of flexibility in applying both face-to-face and online components, the flipped, mixed, and online practicing models are frequently used. However, depending on teaching goals and actual conditions, blended learning models, when properly applied, can promote their respective strengths [2] [5]. Therefore, in practice and in new research, educators should consider applying different blended learning models to clarify each model's advantages and disadvantages.

Concerning the second research question, it can be seen that various qualitative, quantitative, mixed methods, study designs, and assessment tools have been used in research on mobility in using blended learning in mathematics teacher education. The results show that research designs have been examined, such as empirical, quasi-experimental, case studies, surveys, and various tools such as tests, interviews, questionnaires, observation, and self-reflective journals and final products. Others have been used to collect data on the effectiveness and difficulties of blended learning concerning aspects of students' knowledge, skills, and attitudes. Experimental studies and evaluation through observation and interviews are commonly used in research studies. This shows the feasibility of empirical studies in blended learning research and the effectiveness of qualitative tools such as observation and interviews. However, new studies may develop novel study designs or assessment tools to achieve meaningful new findings.

The third research question looked into the advantages students might experience from enrolling in programs that use blended learning strategies. Regarding knowledge, many studies show that blended learning positively impacts students' formation of content knowledge and pedagogical knowledge, particularly given the feature of combining face-to-face and online components. However, the online component is the component that is of interest in most research on blended learning. When participating in these courses, students also develop knowledge related to technical factors, including technological knowledge, technological pedagogical knowledge, and technological content knowledge. Thus, some studies test the progress of students' learning outcomes after an extended period of studying with blended learning. A study by [50] conducted a controlled experiment from 2019 to 2020 to show the improvement in the academic performance of mathematics preservice teachers in the experimental group across each subject through the application of blended learning. Systematic reviews by [5] and [9] found similar results.

However, [33] reported a different empirical result in one of the selected studies. Specifically, for the four aspects of modeling, interpretation, translation and reification in forming students' conceptual knowledge, blended learning had almost no significant influence on the first three components. As regards skills, studies show a positive impact of blended learning on students' higher-order thinking abilities, most notably creative thinking and problem-solving [35] [46] [47]. Moreover, professional skills such as technology application, pedagogical, and research skills are developed. In addition, through independent learning and online Discussion, the students participating in these studies also practiced independent study skills, communication skills, social interaction skills, and social skills of teamwork and cooperation.

Regarding the effects of blended learning on students' attitudes, studies have shown that students have more positive learning attitudes, are motivated to learn, and actively participate in learning. In addition, thanks to the encouraging characteristics of self-study, students are stimulated with self-directed learning readiness, self-efficacy, self-regulation, and a sense of learning due to the online platforms of blended learning courses and their practice and awareness of ICT applications. In addition, several studies have shown that blended learning saves time in class for students, leaving them with more time to spend on self-study and practice; study costs are also reduced, thanks to some of the internet's affordable and free online learning platforms [42] [51]. The study [58] proved that promoting an online teaching model that gives students hands-on training and helps them enhance their online learning experience positively impacts student learning. With such diverse benefits, blended learning needs to be applied more widely in studies involving other fields, and at the same time, new studies should investigate the impact of blended learning on other specific aspects of producing more profound results.

The final research question analyzed the challenges of applying blended learning in the selected studies. Regarding the technology factor, research shows that the problems of infrastructure, technical problems, tool selection, and the language of technological tools are significant challenges for lecturers or learners. Deficiencies in facilities and technology constitute challenges for some developing and undeveloped countries. Therefore, investment in developing facilities at universities should be prioritized. Thus, there is a need for cooperation and support between countries to facilitate the development of blended learning in areas with socio-economic conditions that do not possess the requisite technical facilities. The same suggestion is also mentioned in the study [7]. In addition, it is necessary to conduct studies on the development or application of tools to support blended learning and clarify the tools' operational methods, advantages, and disadvantages. In addition to digital tools, educational technologies that have been proven to be useful for online teaching and learning, such as project-based learning [59 – 64] and other active learning pedagogies [65], can be taken into consideration. It is essential to do this in order to choose the appropriate tools for various educational objectives and environments while also overcoming the technical limitations of technique and language.

In addition, mathematics preservice teachers must actively learn about different tools and improve their ability to use them, as well as their facility with foreign languages, to achieve the prerequisites for applying technology and techniques in teaching with blended learning. Regarding the preparation of teaching and learning materials, many studies have pointed out challenges for teachers in blended learning material resources, suitability in course content quality, lesson plans and activities, questions, and the time needed to prepare lectures and allocate time during lectures. This result aligns with the findings of [23] and [66] about the challenges of transitioning from in-person to online learning. Furthermore, issues such as the mental health impacts

of remote learning and isolation [66] and the time of day of instruction that affects student learning [67] can be considered as interesting directions for future research. In addition, a study [52] showed that the limitations of implementing continuous formative assessment, proximity, and eye contact also affect teachers' ability to assess students' knowledge acquisition. Finally, the research considers the requirements for the capacity of teachers and students to apply ICTs, the professional qualifications of the teachers, the ability to transform knowledge, and the participation of students in learning significant knowledge for the effectiveness of applying blended learning in mathematics teacher education. In line with this, [68] stated that education in the 21st century is about training graduates with various competencies, reducing the gap between the classroom and the real-world environment via professional practice, and simulating a work environment in the curriculum. On this score, in addition to the efforts of teachers and students in developing information technology application skills or professional development, educational managers and educational institutions need to come up with solutions concerning professional development for teachers. Such considerations should include teaching expertise, technology application, and skills in information technology application to prepare teaching and learning materials (e.g., plans, technological tools, and assessment instruments). In addition, new studies need to pay attention to the influence of the challenges mentioned above on the effectiveness and feasibility of applying blended learning and should propose appropriate solutions.

5 LIMITATIONS

Although various methods have been selected to avoid bias, the study has potential selection and publication bias limitations. In addition, the collection of studies in the Scopus catalog searched from databases such as Scopus, ScienceDirect, Taylor & Francis Online, Mendeley, Google Scholar, and ERIC may create certain limitations. In the search process, for example, limit the number of studies that can be selected because, in other databases besides Scopus, there may be many other articles on applying blended learning in the education of mathematics teachers. However, due to the ubiquity of the Scopus catalog, this search method also makes it easier to select high-impact studies. In subsequent systematic reviews, methods to minimize bias in research collection and the selection of databases and data collection methods should be a priority. Additionally, new studies may consider expanding the database in research search, increasing the rigor of inclusion and exclusion criteria, and expanding the sample size of studies selected while still ensuring the quality of those studies.

In terms of content, during the analysis of selected studies, it is possible to recognize many differences in the level of detail of the studies in describing the blended learning model, the study design, and the research design as well as the benefits and challenges of applying blended learning. In other words, the fact that some studies only cover the above issues can affect the analysis's level of detail and accuracy. Besides, although the blended learning models used in the selected studies have a combination of face-to-face and online components, most studies focus mainly on analyzing the characteristics, benefits, or challenges of online components; this was confirmed earlier in the study [8]. Therefore, this study could not deeply explore aspects related to the role of face-to-face components in blended learning. Therefore, future studies on blended learning need to clarify the research designs and describe in detail the models and activities of blended learning that have been used experimentally to provide complete information and a valuable reference for those interested in this topic. Besides, new studies

can consider face-to-face and online components in applying blended learning (e.g., characteristics, roles, teaching design principles) or focus mainly on face-to-face components in blended learning.

6 CONCLUSION

This systematic review analyzed studies on the application of blended learning in undergraduate mathematics teaching by preservice teachers. The study has synthesized analytical results in many aspects, corresponding to the research questions posed, including (1) the characteristics of the year and country of publication, the mathematical topic, and the model of blended learning used in research; (2) the research methods, study design, and assessment tools used in the selected studies; (3) the benefits of applying blended learning in mathematics teachers' education mentioned in the studies; and (4) the challenges posed when applying blended learning in mathematics teachers education mentioned in the studies. Specifically, research on blended learning in mathematics teacher education tends to increase from 2019 to 2022 and is done more in developing countries. In addition to its application in teaching mathematics subjects, blended learning is also applied in many subjects about mathematics teaching methods and commonly used models, including the flipped model, mixed model, and online practicing model. These studies combine qualitative and quantitative methods with various research designs, the most popular of which include experimental methods and assessment tools such as interviews, questionnaires, observation, tests, and output products. The selected studies mention benefits in three main aspects: knowledge, skills, and attitudes of students, and the benefits of saving time and money on tools. Accordingly, after studying with blended learning, students have developed content knowledge, pedagogical knowledge, and technological knowledge; improved academic performance; developed higher-order thinking, pedagogical skills, ICT application skills, and other soft skills such as communication, cooperation, and independent learning; as well as raised awareness and a positive attitude toward learning, self-directed learning readiness, self-regulation, and self-efficacy. On the other hand, studies also point to challenges in applying blended learning to teaching, including technological challenges such as infrastructure, technical problems, tool selection, and language of technological tools; learning and teaching materials challenges such as teaching and learning resources, course content quality, lesson plans and learning activities, and acquisition questions, as well as course preparation time, time distribution in lessons, and limitations in assessment; and finally, challenges related to lecturers and student's ability to use ICTs, the reliance on lecturer's professional development, students engagement and knowledge transfer abilities.

This study's results can be considered a reference for future studies on blended learning, providing educators with an overview of research related to blended learning applications in mathematics teacher education for 2012–2022. In addition, limitations of the study or aspects that this study has not analyzed can be considered for future new research, such as (1) performing systematic reviews on an aspect specifically when applying blended learning (e.g., models, teaching designs, advantages, challenges and solutions) in other fields of education, (2) conducting studies on face-to-face components in blended learning, (3) conduct studies on the influence of blended learning on the development of specific types of competencies and skills, or (4) the effectiveness of different technological tools in blended learning, such as mediating tool [69] and mechanism for evaluating distance education [70], and (5) exploring the fundamental needs and satisfaction of learners in online learning [71].

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8 REFERENCES

[1] N. Muhammad and S. Srinivasan, "Transition from In-class to Online Lectures during a Pandemic," *Visions and Concepts for Education 4.0*, Eds M. E. Auer and D. Centea, ICBL 2020, AISC 1314, Springer Nature, Switzerland, pp. 1–8, 2021.

[2] A. Alammary, "Blended Learning Models for Introductory Programming Courses: A Systematic Review," *PLOS ONE*, vol. 14, no. 9, p. e0221765, 2019. https://doi.org/10.1371/journal.pone.0221765

[3] A. A. Çobanoğlu, "Student Teachers' Satisfaction for Blended Learning Via Edmodo Learning Management System," (in en), *Behaviour & Information Technology*, vol. 37, no. 2, pp. 133–144, 2018. https://doi.org/10.1080/0144929X.2017.1417481

[4] C. B. Juhl and H. Lund, "Do We Really Need Another Systematic Review?" (in en), *British Journal of Sports Medicine*, vol. 52, no. 22, pp. 1408–1409, 2018. https://doi.org/10.1136/bjsports-2018-099832

[5] M. A. Ashraf, M. Yang, Y. Zhang, M. Denden, A. Tlili, J. Liu, R. Huang, and D. Burgos, "A Systematic Review of Systematic Reviews on Blended Learning: Trends, Gaps and Future Directions," (in en), *Psychology Research and Behavior Management*, vol. 14, pp. 1525–1541, 2021. https://doi.org/10.2147/PRBM.S331741

[6] A. Atmacasoy and M. Aksu, "Blended Learning at Preservice Teacher Education in Turkey: A Systematic Review," *Education and Information Technologies*, vol. 23, no. 6, pp. 2399–2422, 2018. https://doi.org/10.1007/s10639-018-9723-5

[7] B. Birgili, F. N. Seggie, and E. Oğuz, "The Trends and Outcomes of Flipped Learning Research between 2012 and 2018: A Descriptive Content Analysis," (in en), *Journal of Computers in Education*, vol. 8, no. 3, pp. 365–394, 2021. https://doi.org/10.1007/s40692-021-00183-y

[8] R. Boelens, B. De Wever, and M. Voet, "Four Key Challenges to the Design of Blended Learning: A Systematic Literature Review," (in en), *Educational Research Review*, vol. 22, pp. 1–18, 2017. https://doi.org/10.1016/j.edurev.2017.06.001

[9] F.-D. Fernández-Martín, J.-M. Romero-Rodríguez, G. Gómez-García, and M. Ramos Navas-Parejo, "Impact of the Flipped Classroom Method in the Mathematical Area: A Systematic Review," (in en), *Mathematics*, vol. 8, no. 12, p. 2162, 2020. https://doi.org/10.3390/math8122162

[10] R. A. Rasheed, A. Kamsin, and N. A. Abdullah, "Challenges in the Online Component of Blended Learning: A Systematic Review," (in en), *Computers & Education*, vol. 144, p. 103701, 2020. https://doi.org/10.1016/j.compedu.2019.103701

[11] A. Alammary, J. Sheard, and A. Carbone, "Blended Learning in Higher Education: Three Different Design Approaches," *Australasian Journal of Educational Technology*, vol. 30, no. 4, 2014. https://doi.org/10.14742/ajet.693

[12] R. Castro, "Blended Learning in Higher Education: Trends and Capabilities," *Education and Information Technologies*, vol. 24, no. 4, pp. 2523–2546, 2019. https://doi.org/10.1007/s10639-019-09886-3

[13] M. Goos, J. O'Donoghue, M. Ní Ríordáin, F. Faulkner, T. Hall, and N. O'Meara, "Designing a National Blended Learning Program for 'Out-of-Field' Mathematics Teacher Professional Development," *ZDM Mathematics Education*, vol. 52, no. 5, pp. 893–905, 2020. https://doi.org/10.1007/s11858-020-01136-y

[14] M. B. Horn and H. Staker, "*Blended: Using Disruptive Innovation to Improve Schools*," 1 ed. San Francisco, CA: Jossey-Bass, A Wiley Brand, p. 1, 2014.

[15] J. Engelbrecht, S. Llinares, and M. C. Borba,"Transformation of the Mathematics Classroom with the Internet," *ZDM Mathematics Education*, vol. 52, no. 5, pp. 825–841, 2020. https://doi.org/10.1007/s11858-020-01176-4

[16] N. Muhammad and S. Srinivasan, "Online Education During a Pandemic – Adaptation and Impact on Student Learning," *Int. J. Engineering Pedagogy*, vol. 11, no. 3, pp. 71–83, 2021. https://doi.org/10.3991/ijep.v11i3.20449

[17] S. Martínez, F. Guíñez, R. Zamora, S. Bustos, and B. Rodríguez, "On the Instructional Model of a Blended Learning Program for Developing Mathematical Knowledge for Teaching," (in en), *ZDM Mathematics Education*, vol. 52, no. 5, pp. 877–891, 2020. https://doi.org/10.1007/s11858-020-01152-y

[18] Y. K. Hui, C. Li, S. Qian, and L. F. Kwok, "Learning Engagement Via Promoting Situational Interest in a Blended Learning Environment," *Journal of Computing in Higher Education*, vol. 31, no. 2, pp. 408–425, 2019. https://doi.org/10.1007/s12528-019-09216-z

[19] R. Rasmitadila, W. Widyasari, M. A. Humaira, A. R. S. Tambunan, R. Rachmadtullah, and A. Samsudin, "Using Blended Learning Approach (BLA) in Inclusive Education Course: A Study Investigating Teacher Students' Perception," *Int. J. Emerg. Technol. Learn.*, vol. 15, no. 2, pp. 72–85, 2020. https://doi.org/10.3991/ijet.v15i02.9285

[20] K. B. Fedorov, O. N. Imas, A. I. Sherstneva, and S. V. Kriviakov, "Blended Learning and Fundamental Disciplines," in *Interactive Collaborative Learning*, Cham, M. E. Auer, D. Guralnick, and J. Uhomoibhi, Eds., Springer International Publishing, pp. 142–153, 2017. https://doi.org/10.1007/978-3-319-50340-0_11

[21] O. Ketsman, "Perspectives of Preservice Teachers About Blended Learning in Technology Integration Courses," (in en), *International Journal of Mobile and Blended Learning*, vol. 11, no. 4, pp. 15–31, 2019. https://doi.org/10.4018/IJMBL.2019100102

[22] S. Pozo Sánchez, J. López Belmonte, A. J. Moreno Guerrero, and F. J. Hinojo-Lucena, "Flipped Learning Y Competencia Digital: Una Conexión Docente Necesaria Para Su Desarrollo En La Educación Actual," *Revista Electrónica Interuniversitaria de Formación del Profesorado*, vol. 23, no. 2, 2020. https://doi.org/10.6018/reifop.422971

[23] S. Srinivasan, J. A. L. Ramos, and N. Muhammad, "A Flexible Future Education Model-Strategies Drawn from Teaching during the COVID-19 Pandemic," *Educ. Sci.*, vol. 11, p. 557, 2021. https://doi.org/10.3390/educsci11090557

[24] B. Atweh, B. Kaur, G. Nivera, A. Abadi, and S. Thinwiangthong, "Futures for Post-Pandemic Mathematics Teacher Education: Responsiveness and Responsibility in the Face of a Crisis," (in en), *ZDM Mathematics Education*, vol. 55, pp. 65–77, 2023. https://doi.org/10.1007/s11858-022-01394-y

[25] M. Mishiwo, C. Lokpo, and M. D. Adane, "Learning Mathematics Online: Preservice Teachers' Competences and Challenges," *British Journal of Education*, vol. 10, no. 2, pp. 42–55, 2022. https://doi.org/10.37745/bje/vol10.no1.pp42-55

[26] O. Yaw, "Readiness in Using Blended Approach in College Education," *Journal of Mathematics and Science Teacher*, vol. 2, no. 2, 2022. https://doi.org/10.29333/mathsciteacher/12408

[27] N. F. Buchholtz, N. Krosanke, A. B. Orschulik, and K. Vorhölter, "Combining and Integrating Formative and Summative Assessment in Mathematics Teacher Education," (in en), *ZDM Mathematics Education*, vol. 50, no. 4, pp. 715–728, 2018. https://doi.org/10.1007/s11858-018-0948-y

[28] J. Silverman and V. Hoyos, Eds. "Distance Learning, E-Learning and Blended Learning," In *Mathematics Education: International Trends in Research and Development (ICME-13 Monographs)*. Cham: Springer International Publishing (in en), 2018. https://doi.org/10.1007/978-3-319-90790-1

[29] D. Moher, A. Liberati, J. Tetzlaff, D. G. Altman, and P. G. The, "Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement," (in en), *PLoS Medicine*, vol. 6, no. 7, p. e1000097, 2009. https://doi.org/10.1371/journal.pmed.1000097

[30] D. Moher, A. Liberati, J. Tetzlaff, and D. G. Altman, "Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement," (in en), *International Journal of Surgery*, vol. 8, no. 5, pp. 336–341, 2010. https://doi.org/10.1016/j.ijsu.2010.02.007

[31] C. Fernández, S. Llinares, and J. Valls, "Learning to Notice Students' Mathematical Thinking through Online Discussions," *ZDM Mathematics Education*, vol. 44, no. 6, pp. 747–759, 2012. https://doi.org/10.1007/s11858-012-0425-y

[32] D. D. Agyei and J. M. Voogt, "Preservice Teachers' TPACK Competencies for Spreadsheet Integration: Insights from a Mathematics-Specific Instructional Technology Course," (in en), *Technology, Pedagogy and Education*, vol. 24, no. 5, pp. 605–625, 2015. https://doi.org/10.1080/1475939X.2015.1096822

[33] A. Roux, H. Nieuwoudt, and S. Nieuwoudt, "Conceptual Learning of Functions in a Technologically Enhanced Environment," *African Journal of Research in Mathematics, Science and Technology Education*, vol. 19, no. 3, pp. 289–305, 2015. https://doi.org/10.1080/10288457.2015.1089674

[34] H. J. Heo and B. A. Chun, "Improving the Higher Order Thinking Skills Using Flipped Learning: Focused on the In-Class Activities with Problem Posing and Solving," *Asia Life Sciences*, vol. 15, no. 4, pp. 2187–2200, 2018.

[35] D. Fisher and Y. S. Kusumah, "Developing Student Character of Preservice Mathematics Teachers through Blended Learning," *Journal of Physics: Conference Series*, vol. 1132, p. 012040, 2018. https://doi.org/10.1088/1742-6596/1132/1/012040

[36] H. J. Heo and B. A. Chun, "A Study on the Effects of Mobile-based LMS on Flipped Learning: Focused on the Affective Pathway in Preservice Teacher Education," *International Journal of Software Engineering and Its Applications*, vol. 10, no. 12, pp. 473–484, 2016. https://doi.org/10.14257/ijseia.2016.10.12.39

[37] C. Romero, O. Buzón-García, and J. Touron, "The Flipped Learning Model in Online Based Education for Secondary Teachers," *Journal of Technology and Science Education*, vol. 9, no. 2, p. 13, 2019. https://doi.org/10.3926/jotse.435

[38] M. Sintawati and G. Abdurrahman, "The Effectiveness of Blended Learning to Improve Preservice Teacher TPACK in Developing Multimedia Learning Mathematics at Elementary School," *Journal of Physics: Conference Series*, vol. 1521, no. 3, p. 032014, 2020. https://doi.org/10.1088/1742-6596/1521/3/032014

[39] K. Umam, T. Nusantara, I. N. Parta, E. Hidayanto, and H. Mulyono, "An Application of Flipped Classroom in Mathematics Teacher Education Programme," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 13, no. 3, pp. 68–80, 2019. https://doi.org/10.3991/ijim.v13i03.10207

[40] W. W. W. Brata, C. Suriani, H. Simatupang, S. Siswanto, and F. T. M. Panggabean, "Prospective Science Teachers' Learning Independency Level on Blended Learning," *Journal of Physics: Conference Series*, vol. 1462, no. 1, p. 012070, 2020. https://doi.org/10.1088/1742-6596/1462/1/012070

[41] R. Cendros Araujo and G. Gadanidis, "Online Collaborative Mind Mapping in a Mathematics Teacher Education Program: A Study on Student Interaction and Knowledge Construction," *ZDM Mathematics Education*, vol. 52, no. 5, pp. 943–958, 2020. https://doi.org/10.1007/s11858-019-01125-w

[42] J. Naidoo, "Exploring the Flipped Learning Approach within a Mathematics Higher Education Milieu in the Era of the Fourth Industrial Revolution," (in en), *Universal Journal of Educational Research*, vol. 8, no. 6, pp. 2542–2553, 2020. https://doi.org/10.13189/ujer.2020.080638

[43] Rohana and Y. L. Ningsih, "Statistical Reasoning of Prospective Teachers through Blended Learning," *Journal of Physics: Conference Series*, vol. 1480, no. 1, p. 012006, 2020. https://doi.org/10.1088/1742-6596/1480/1/012006

[44] E. Ö. Şen and K. Hava, "Prospective Middle School Mathematics Teachers' Points of View on the Flipped Classroom: The Case of Turkey," *Education and Information Technologies*, vol. 25, no. 5, pp. 3465–3480, 2020. https://doi.org/10.1007/s10639-020-10143-1

[45] I. J. A. Ubah, E. D. Spangenberg, and V. Ramdhany, "Blended Learning Approach to Mathematics Education Modules: An Analysis of Preservice Teachers' Perceptions," *International Journal of Learning, Teaching and Educational Research*, vol. 19, no. 7, pp. 298–319, 2020. https://doi.org/10.26803/ijlter.19.7.17

[46] W. Wahyudi, S. B. Waluya, H. Suyitno, and I. Isnarto, "The Impact of 3CM Model within Blended Learning to Students' Creative Thinking Ability," *Journal of Technology and Science Education*, vol. 10, no. 1, p. 15, 2020. https://doi.org/10.3926/jotse.588

[47] A. Aristika, Darhim, D. Juandi, and Kusnandi, "The Effectiveness of Hybrid Learning in Improving of Teacher-Student Relationship in Terms of Learning Motivation," *Emerging Science Journal*, vol. 5, no. 4, pp. 443–456, 2021. https://doi.org/10.28991/esj-2021-01288

[48] W. Daher, K. Sabbah, and M. Abuzant, "Affective Engagement of Higher Education Students in an Online Course," *Emerging Science Journal*, vol. 5, no. 4, pp. 545–558, 2021. https://doi.org/10.28991/esj-2021-01296

[49] Y. S. K. Sudirman and Bambang Avip Priatna Martadiputra, "Augmented Reality Blended Learning Instruction: The Impact on Growing Motivation, Attitudes, and Knowledge in 3D Geometry," *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, vol. 12, no. 4, pp. 674–683, 2021. https://doi.org/10.17762/turcomat.v12i4.552

[50] K. V. Vlasenko, I. V. Lovianova, O. G. Rovenska, T. S. Armash, and V. V. Achkan, "Development of the Online Course for Training Master Students Majoring in Mathematics," *Journal of Physics: Conference Series*, vol. 1946, no. 1, p. 012001, 2021. https://doi.org/10.1088/1742-6596/1946/1/012001

[51] A. Arabaci and K. Orbay, "Impact of Experiencing Event Design with Web 2.0 Tools on Prospective Mathematics Teachers," (in en), *Problems of Education in the 21st Century*, vol. 80, no. 1, pp. 52–68, 2022. https://doi.org/10.33225/pec/22.80.52

[52] R. Araújo Filho and V. Gitirana, "Preservice Teachers' Knowledge: Analysis of Teachers' Education Situation Based on TPACK," (in en), *The Mathematics Enthusiast*, vol. 19, no. 2, pp. 594–631, 2022. https://doi.org/10.54870/1551-3440.1565

[53] H. Hardi, W. Wahyudi, H. Suyitno, K. Kartono, and Y. Sukestiyarno, "The Mathematic Connection Ability of Preservice Teacher during Online Learning According to Their Learning Style," *Journal of Technology and Science Education (JOTSE)*, vol. 12, no. 1, pp. 230–243, 2022. https://doi.org/10.3926/jotse.1198

[54] S. Maarif, K. Umam, J. Soebagyo, and T. R. Pradipta, "Critical Review on Mathematics Virtual Classroom Practice in Private University," *International Journal of Nonlinear Analysis and Applications*, vol. 13, no. 1, pp. 975–982, 2022. https://doi.org/10.22075/ijnaa.2022.5616

[55] G. Sunzuma, N. Zezekwa, T. L. Mutambara, C. Chagwiza, and I. Gwizangwe, "Preservice Teachers' Whatsapp Preferences in a Mathematics Methodology Course during the COVID-19 Pandemic," *Open Education Studies*, vol. 4, no. 1, pp. 225–240, 2022. https://doi.org/10.1515/edu-2022-0014

[56] F. L. Gaol and F. Hutagalung, "The Trends of Blended Learning in South East Asia," (in en), *Education and Information Technologies*, vol. 25, no. 2, pp. 659–663, 2020. https://doi.org/10.1007/s10639-020-10140-4

[57] H.-C. Lin and G.-J. Hwang, "Research Trends of Flipped Classroom Studies for Medical Courses: A Review of Journal Publications from 2008 to 2017 Based on the Technology-Enhanced Learning Model," (in en), *Interactive Learning Environments*, vol. 27, no. 8, pp. 1011–1027, 2019. https://doi.org/10.1080/10494820.2018.1467462

[58] M. Alavi and S. Srinivasan, "Introduction of Online Labs to Enhance the Quality of the Real-Time Systems Course," in *New Realities, Mobile Systems and Applications*, eds M. E. Auer, and T. Tsiatsos, IMCL 2021, Lecture Notes in Networks and Systems, Springer, Cham., vol. 411, 2022. https://doi.org/10.1007/978-3-030-96296-8_77

[59] S. Bogoslowski, F. Geng, Z. Gao, A. Rajabzadeh, and S. Srinivasan, "Integrated Thinking – A Cross-disciplinary Project-Based Engineering Education," in *Visions and Concepts for Education 4.0*, eds M. E. Auer and D. Centea, ICBL 2020, AISC 1314, Springer Nature, Switzerland, pp. 1–7, 2021.

[60] D. Centea and S. Srinivasan, "Enhancing Student Learning through Problem Based Learning," in *Social Progress and Sustainability*, Aalborg: Aalborg Universitetsforlag, Denmark, pp. 376–385, 2017.

[61] D. Centea and S. Srinivasan, "Assessment in Problem-Based Learning Using Mobile Technologies," in *Mobile Technologies and Applications for the Internet of Things*, IMCL 2018, *Advances in Intelligent Systems and Computing*, Springer Nature, Switzerland, pp. 337–346, 2019. https://doi.org/10.1007/978-3-030-11434-3_37

[62] D. Centea and S. Srinivasan, "Collaboration with Industry in the Development and Assessment of a PBL Course," in *Visions and Concepts for Education 4.0*, eds M. E. Auer and D. Centea, ICBL 2020, AISC 1314, Springer Nature, Switzerland, pp. 1–7, 2021.

[63] F. Geng, S. Srinivasan, Z. Gao, S. Bogoslowski, and A. R. Rajabzadeh, "An Online Approach to Project-Based Learning in Engineering and Technology for Post-secondary Students," in *New Realities, Mobile Systems and Applications*, eds M. E. Auer, and T. Tsiatsos, IMCL 2021. Lecture Notes in Networks and Systems, Springer, Cham., vol. 411, 2022. https://doi.org/10.1007/978-3-030-96296-8_56

[64] G. Sidhu, S. Srinivasan, and D. Centea, "Implementation of a Problem Based Learning Environment for First Year Engineering Mathematics," in *Social Progress and Sustainability*, Aalborg: Aalborg Universitetsforlag, Denmark, pp. 201–208, 2017.

[65] S. Srinivasan and D. Cente, "Applicability of Principles of Cognitive Science in Active Learning Pedagogies," in *Proceedings of the 13th International Workshop Active Learning in Engineering*, Aalborg: Aalborg Universitetsforlag, Denmark, pp. 99–104, 2015.

[66] L. A. Grieves, J. McKendry, N. Muhammad, and S. Srinivasan, "The Transition from In-class to Online Lectures During a Pandemic: Understanding the Student Experience," *Int. J. Eng. Educ*., vol. 38, no. 2, pp. 376–392, 2022.

[67] S. Srinivasan and N. Muhammad, "Effect of the Time of Day of Instruction on Student Learning," *International Journal of Pedagogy and Teacher Education*, vol. 4, no. 2, pp. 126–137, 2020. https://doi.org/10.20961/ijpte.v4i2.43070

[68] A. R. Rajabzadeh, M. Mehrtash, and S. Srinivasan, "Multidisciplinary Problem-Based Learning (MPBL) Approach in Undergraduate Programs," in *New Realities, Mobile Systems and Applications*, eds M. E. Auer, and T. Tsiatsos, IMCL 2021. Lecture Notes in Networks and Systems, Springer, Cham., vol. 411, 2022. https://doi.org/10.1007/978-3-030-96296-8_41

[69] C. Pham Kim, T. Ho Thi Ngoc, H. Nguyen Thi Thu, K. Bui Thi Diem, A. Nguyen Hoang Thai, and L. Nguyen Thi Thuy, "Exploring Students' Engagement of Using Mediating Tools in E-learning," *Int. J. Emerg. Technol. Learn.*, vol. 17, no. 19, pp. 4–19, 2022. https://doi.org/10.3991/ijet.v17i19.31655

[70] M. Amraouy, M. Bellafkih, A. Bennane, and J. Talaghzi, "Toward an Effective Model for Evaluating Distance Education," *Int. J. Emerg. Technol. Learn.*, vol. 18, no. 4, pp. 16–31, 2023. https://doi.org/10.3991/ijet.v18i04.35167

[71] T. T. H. Phuong, "Prolonged Online Learning: An Exploratory Mixed-Methods Study on EFL Learners' Needs and Need Satisfaction: Online Learning: Needs and Need Satisfaction," *Int. J. Emerg. Technol. Learn.*, vol. 18, no. 4, pp. 186–201, 2023. https://doi.org/10.3991/ijet.v18i04.35759

9 APPENDIX

Paper ID	Author	Country	Year	Title	Journal	Ref.
P1	Agyei & Voogt	Ghana	2015	Preservice Teachers' TPACK Competencies For Spreadsheet Integration: Insights From A Mathematics-Specific Instructional Technology Course	Technology, Pedagogy and Education	[32]
P2	Arabaci & Orbay	Turkey	2022	Impact Of Experiencing Event Design With Web 2.0 Tools On Prospective Mathematics Teachers	Problems of Education in the 21st Century	[51]
P3	Araújo Filho & Gitirana	Brazil	2022	Preservice Teachers' Knowledge: Analysis Of Teachers' Education Situation-Based On TPACK	The Mathematics Enthusiast	[52]
P4	Aristika et al.	Indonesia	2021	The Effectiveness Of Hybrid Learning In Improving Of Teacher-student Relationship In Terms Of Learning Motivation	Emerging Science Journal	[47]
P5	Brata et al.	Indonesia	2020	Prospective Science Teachers' Learning Independency Level On Blended Learning	IOP Conf. Series: Journal of Physics: Conf. Series	[40]
P6	Cendros Araujo & Gadanidis	Canada	2020	Online Collaborative Mind Mapping In A Mathematics Teacher Education Program: A Study On Student Interaction And Knowledge Construction	ZDM Mathematics Education	[41]
P7	Daher et al.	Palestine	2021	Affective Engagement Of Higher Education Students In An Online Course	Emerging Science Journal	[48]
P8	Fernández et al.	Spain	2012	Learning To Notice Students' Mathematical Thinking Through Online Discussions	ZDM Mathematics Education	[31]
P9	Fisher & Kusumah	Indonesia	2018	Developing Student Character Of Preservice Mathematics Teachers Through Blended Learning	Journal of Physics: Conf. Series	[35]
P10	Hardi et al.	Indonesia	2022	The Mathematic Connection Ability Of Preservice Teacher During Online Learning According To Their Learning Style	Journal of Technology and Science Education	[53]
P11	Heo & Chun	Korean	2016	A Study On The Effects Of Mobile-Based LMS On Flipped Learning: Focused On The Affective Pathway In Preservice Teacher Education	International Journal of Software Engineering and Its Applications	[36]
P12	Heo & Chun	Korean	2018	Improving The Higher Order Thinking Skills Using Flipped Learning: Focused On The In-Class Activities With Problem Posing And Solving	Asia Life Sciences	[34]
P13	Maarif et al.	Indonesia	2022	Critical Review On Mathematics Virtual Classroom Practice In Private University	Int. J. Nonlinear Anal. Appl.	[54]
P14	Naidoo	South Africa	2020	Exploring The Flipped Learning Approach Within A Mathematics Higher Education Milieu In The Era Of The Fourth Industrial Revolution	Universal Journal of Educational Research	[42]
P15	Rohana & Ningsih	Indonesia	2020	Statistical Reasoning Of Prospective Teachers Through Blended Learning	Journal of Physics: Conference Series	[43]

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Paper ID	Author	Country	Year	Title	Journal	Ref.
P16	Romero et al.	Spain	2018	The Flipped Learning Model In Online Education For Secondary Teachers	Journal of Technology and Science Education	[37]
P17	Roux et al.	South Africa	2015	Conceptual Learning Of Functions In A Technologically Enhanced Environment	Journal of Research in Mathematics, Science and Technology Education	[33]
P18	Şen & Hava	Turkey	2020	Prospective Middle School Mathematics Teachers' Points Of View On The Flipped Classroom: The Case Of Turkey	Education and Information Technologies	[44]
P19	Sintawati & Abdurrahman	Indonesia	2019	The Effectiveness Of Blended Learning To Improve Preservice Teacher Tpack In Developing Multimedia Learning Mathematics At Elementary School	Journal of Physics: Conference Series	[38]
P20	Sudirman et al.	Indonesia	2021	Augmented Reality Blended Learning Instruction: The Impact On Growing Motivation, Attitudes, And Knowledge In 3D Geometry	Turkish Journal of Computer and Mathematics Education	[49]
P21	Sunzuma et al.	Zimbabwe	2022	Preservice Teachers' Whatsapp Preferences In A Mathematics Methodology Course During The COVID-19 Pandemic	Open Education Studies	[55]
P22	Ubah et al.	South Africa	2020	Blended Learning Approach to Mathematics Education Modules: An Analysis of Preservice Teachers' Perceptions	International Journal of Learning, Teaching and Educational Research	[45]
P23	Umam et al.	Indonesia	2019	An Application Of Flipped Classroom In Mathematics Teacher Education Programme	International Journal of Interactive Mobile Technologies	[39]
P24	Vlasenko et al.	Ukraine	2021	Development Of The Online Course For Training Master Students Majoring In Mathematics	Journal of Physics: Conference Series	[50]
P25	Wahyudi et al.	Indonesia	2020	The Impact Of the 3CM Model Within Blended Learning To Enhance Students' Creative Thinking Ability	Journal of Technology and Science Education	[46]

10 AUTHORS

Duong Huu Tong is an Associate Professor and an advanced senior lecturer at the School of Education, Can Tho University, Can Tho City, Vietnam. His research areas include mathematics education, educational evaluation, and curriculum development, among other things, over the past 19 years (E-mail: dhtong@ctu.edu.vn).

Bui Phuong Uyen is also an Associate Professor. As an advanced senior lecturer at the School of Education at Can Tho University where she has worked since 2008. Her research interests include mathematics education, educational evaluation, information and communication technology applications in education, and teacher education (E-mail: bpuyen@ctu.edu.vn).

Lu Kim Ngan is a master student who graduated in Principles and Methods of Teaching Mathematics at Can Tho University and is continuing her research in this field (E-mail: lukimnganltt@gmail.com).