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Blended Learning in Mathematics Education: A Bibliometric Analysis of Research Trends and Patterns

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Article Info

Abstract

Article History

Received:
6 August 2025

Revised:
21 December 2025

Accepted:
15 January 2026

Published:
27 March 2026

Keywords

Blended learning
Mathematics education
Bibliometric
Scopus

Blended learning has become a prominent instructional approach in mathematics education, offering flexible and interactive strategies that enhance student engagement and learning effectiveness. Given its growing importance, a comprehensive bibliometric analysis is needed to clarify current research trends, influential contributors, and key themes. This study analyzed 295 Scopus-indexed publications from 1999 to 2025, employing OpenRefine, biblioMagika®, and VOSviewer for data processing and visualization. Findings highlight a steady increase in blended learning research, peaking at 58 publications in 2023. Leading contributing countries include Indonesia and the United States, while Universitas Pendidikan Indonesia is identified as the most influential institution. Thematic analysis identifies blended learning, flipped classroom, and mathematics education as dominant research clusters. These clusters underscore the importance of digital integration and innovative pedagogies for enhancing student competencies and academic outcomes. Future research should investigate underexplored pedagogical methods, integrate emerging technologies, and explicitly focus on the development of higher-order thinking skills. Addressing these aspects can substantially improve blended learning practices, enhance mathematical understanding, and better equip students with the essential skills required to meet contemporary educational demands.

Citation: Abd Rahman, K. & Abd Halim, N. D. (2026). Blended learning in mathematics education: A bibliometric analysis of research trends and patterns. *International Journal of Education in Mathematics, Science and Technology (IJEMST)*, 14(3), 717-736. <https://doi.org/10.46328/ijemst.5420>



ISSN: 2147-611X / © International Journal of Education in Mathematics, Science and Technology (IJEMST).
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Introduction

Blended learning has the potential to transform teaching and learning by offering flexible, continuous, and efficient learning opportunities. The necessity for changing conventional educational practices particularly during the pandemic has accelerated the adoption of this approach. Educational institutions around the world have shifted from face-to-face instruction to blended learning modes to ensure educational continuity (Ashraf et al., 2021). Recognizing blended learning's capability to support uninterrupted learning, many institutions have continued implementing this approach even after the pandemic (Van der Westhuizen & Hlatshwayo, 2023). With its capacity to combine the strengths of traditional and digital pedagogies, this not only demonstrates the adaptability of blended learning during global disruptions but also affirms its viability as a long-term educational solution.

In mathematics education, blended learning has emerged as a significant trend in technological innovation (Suripah et al., 2025). This approach offers innovative solutions to ongoing pedagogical challenges such as low student engagement and difficulty in understanding abstract concepts. For instance, the implementation of blended learning such as the flipped classroom model promoting student autonomy and collaborative learning through independent online content delivery and utilizing class time for mathematical problem-solving activities and deeper discussions (Güler et al., 2023). On the other hand, station rotation model which integrates face-to-face sessions, computer-based instruction and independent practice enhanced students' engagement and on-task behavior in mathematics learning (Johnson et al., 2024). This approach promoted active participation and collaboration that improved student achievement and conceptual understanding.

Technology integration also plays a crucial role in optimizing the effectiveness of blended learning. Technologies such as interactive digital tools, learning platforms, virtual simulations, and multimedia resources provide visually rich and interactive environments (Cirneanu & Moldoveanu, 2024). This is highly beneficial in mathematics classrooms as they help students grasp challenging mathematical concepts through practical and engaging activities (Suripah et al., 2025) thereby enhancing understanding and knowledge retention. Additionally, learning through these technologies allows teachers to develop personalized instruction suited to different student learning styles (Wang et al., 2024).

In addition to technology integration, the implementation of blended learning also depends on the pedagogical approaches employed. Pedagogical strategies such as project-based and problem-based learning within blended learning enable students to deeply engage with mathematical content through authentic tasks and problem-solving scenarios (Amin et al., 2021; Sari et al., 2022). Grounded in constructivist theories, these student-centered approaches emphasize on collaborative interactions and active knowledge construction. Furthermore, the integration of gamification into blended learning also creates interactive and engaging mathematics classrooms (Bedebayeva et al., 2025). Thus, combining blended learning with strong pedagogical methods can enhance student autonomy, conceptual understanding, and engagement, providing a more meaningful and effective mathematics education experience.

In brief, blended learning has substantial potential to significantly enhance mathematics education by creating

interactive and engaging learning environments beyond traditional instructional methods. As educational institutions worldwide address the evolving demands of 21st-century education, the role of blended learning as an essential approach for improving learner engagement and educational outcomes becomes increasingly clear. Nevertheless, successful implementation relies on robust technological infrastructure and effective teaching practice (Bizami et al., 2023). This bibliometric analysis will examine the current landscape of blended learning research in mathematics education and its future directions, drawing on influential studies that have shaped the understanding of this field.

Literature Review

Emerged in the early 2000s, blended learning has become widely adopted in education today (Ghimire, 2022). Garrison & Kanuka (2004) and Graham (2006) define blended learning as combining traditional instruction with online methods through effective instructional design. Despite challenges posed by COVID-19, blended learning has demonstrated significant potential at school and higher education (Topping et al., 2022) and is expected to shape future educational practices (Bozkurt et al., 2020). It effectively addresses limitations of traditional face-to-face learning such as location, rigid schedules, and time constraints (Cronje, 2022), as well as online learning challenges including limited interaction, low participation, and dropout rates (Khaldi et al., 2023). Ultimately, blended learning represents an adaptable educational strategy suited to various contexts significantly enhancing teaching effectiveness and student outcomes across educational levels.

In mathematics education, traditional lecture-based methods often inadequately address issues related to low student engagement and difficulty in grasping concepts (Nanda & Rani, 2025) thus negatively impacting students' understanding and motivation. However, blended learning strategies have appeared as promising solutions by actively involving students in their learning. For instance, empirical research by Esperanza et al. (2023) demonstrated the effective use of the flipped classroom improved classroom communication and allowing students to progress at their own pace.

Similarly, Egara and Mosimege (2024) also found that students who learned through flipped classroom achieved better performance and interest compared to those taught using traditional methods. This models which delivers instructional content online prior to face-to-face classes, enhances conceptual understanding and promotes greater engagement with mathematical content. Meanwhile, Latif et al. (2024) applied the station rotation model where the students engaged with video lessons and online quizzes found that opportunities for peer collaboration encouraged active participation thus indicating that combining digital tools with group work can enhance engagement in mathematics learning.

The integration of technology in blended learning is essential for improving teaching effectiveness and supports dynamic instructional methods. In mathematics education, interactive platforms and digital simulations enable students to actively explore and visualize mathematical concepts. Supported with findings by Nasrullah et al. (2025), the incorporation of Edmodo platform and GeoGebra software in the blended learning classroom provided students with a more engaging learning experience and enhanced problem-solving skills compared to the control

class where such technological tools were not utilized thus limiting students' opportunities for exploration.

Moreover, technological tools also facilitate real-time assessment, immediate feedback and customized learning pathways that cater to students' individual needs and cognitive styles (Wang et al., 2024). For instance, research by Attard & Holmes (2022) had found that teachers preferred using individual video responses and Learning Management System (LMS) platforms to actively communicate with students beyond school hours. These methods provided accessible, timely, and personalized feedback thereby extending mathematical conversations and supporting the development of students' mathematical thinking.

The combination of pedagogical strategies within blended learning environments further enriches instructional effectiveness in mathematics education. For instance, research by Fitrah et al. (2025) has highlighted the effectiveness of combining project-based learning with flipped classroom. This approach encourages project collaboration and supports self-directed learning using video materials thus allowing students to understand concepts before attending face-to-face sessions. This integrated approach enhances students' computational abilities and equips them to tackle real-world problems, positively impacting broader STEM learning contexts.

Furthermore, Amin et al. (2021) found that the structured approach of blended problem-based learning allows students to actively engage in the analysis and interpretation of findings both independently and collaboratively through online and face-to-face discussions. In addition, Zhao et al. (2021) initiate that gamified flipped learning approach improves student mathematics performance by increasing their engagement and providing peer interaction opportunities. The flipped classroom enables students to prepare and explore concepts independently before class while gamification elements foster deeper engagement and participation thereby boosting students' motivation and self-efficacy.

Given its increasing significance demonstrated by previous empirical research, bibliometric analysis is essential to comprehensively understand the impact and evolving trends of blended learning in mathematics education (Donthu et al., 2021). In this area, Samosir et al. (2023) mapped publications from 2008 to 2023 using keywords such as “blended learning” and “mathematics,” whereas Özdemir (2024) conducted a bibliometric analysis focusing on the flipped classroom model from 2014 to 2023. Meanwhile, Xueli et al. (2025) examined publication patterns from 2004 to 2024 using a broader range of keyword selections. Although these studies establish a foundation for understanding the literature, further bibliometric analysis is still needed through a comprehensive mapping study that covers a longer publication window, employs an inclusive and systematically developed set of search terms to enable broader thematic insights, and clearly reports the data refinement process.

Addressing these identified gaps, this research reviews literature published from 1999 to 2025, providing a comprehensive analysis covering over 25 years of scholarly work. Given that blended learning gained momentum in the early 2000s, initiating the analysis from 1999 establishes an appropriate baseline to understand the evolution of the field and highlight recent developments. Furthermore, accurate and reliable bibliometric outcomes significantly depend on effective data cleaning and harmonization (Ahmi, 2023). Accordingly, this study addresses this methodological need by systematically refining bibliographic data to ensure accuracy and

consistency.

Research Questions

This study presents a bibliometric analysis by addressing four research questions (RQs):

- (1) What is the current state of research on blended learning in mathematics education?
- (2) What publication trends can be identified in blended learning studies within mathematics education?
- (3) Who are the productive authors, institutions, and countries contributing to blended learning research in mathematics education?
- (4) What core research themes underpin blended learning in mathematics education?

Methodology

This study employed bibliographic data retrieved from the Scopus database on 10 July 2025. Scopus was chosen as the primary source due to its extensive coverage of peer-reviewed publications, stringent indexing criteria, and global academic scope, which collectively provide robust metadata suitable for bibliometric analysis. The metadata including citations, author affiliations, publication details, and indexed keywords, facilitated a thorough and precise bibliometric analysis. The datasets such as document and source types, languages, subject, publication trends, authorship, institutional, geographical, and prevalent keywords, enabling a comprehensive analysis of blended learning literature within mathematics education.

Search Strategy

The review adopted the modified PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for conducting systematic research reviews (Page et al., 2021). The search query (“blended learn*” OR “blended course” OR “blended teach*” OR “hybrid learning” OR “blended education” OR “blended e-learning” OR “blended instruction” OR “B-learning” OR “flipped classroom”) AND (“Mathematics Education” OR “Mathematic*” OR “Math*”) was applied in the Scopus database. Correspondingly, subject-specific filters were applied.

This study research scope and coverage were based on the search field, source type, and document types to eliminate irrelevant literature, resulting in 1745 initial documents (see Figure 1). After reviewing the abstracts of these documents, additional exclusions were performed based on topical relevance. Following this filtration process, 275 documents relevant to blended learning in mathematics education were retained for the final analysis.

Figure 1 illustrates the detailed screening steps applied to select relevant studies for this bibliometric analysis. Initially, 1745 documents were identified from the Scopus database. Using automation tools, 782 records were removed as they did not meet the eligibility criteria. These included documents not classified as articles or proceedings and studies as well as titles and abstracts were unrelated to Social Science and Mathematics. As a result, 963 reports remained for further review. However, 644 of these reports could not be retrieved for additional

evaluation. After thoroughly assessing the eligibility of the remaining 319 reports, 24 were excluded for being either non-English or unpublished in final form.

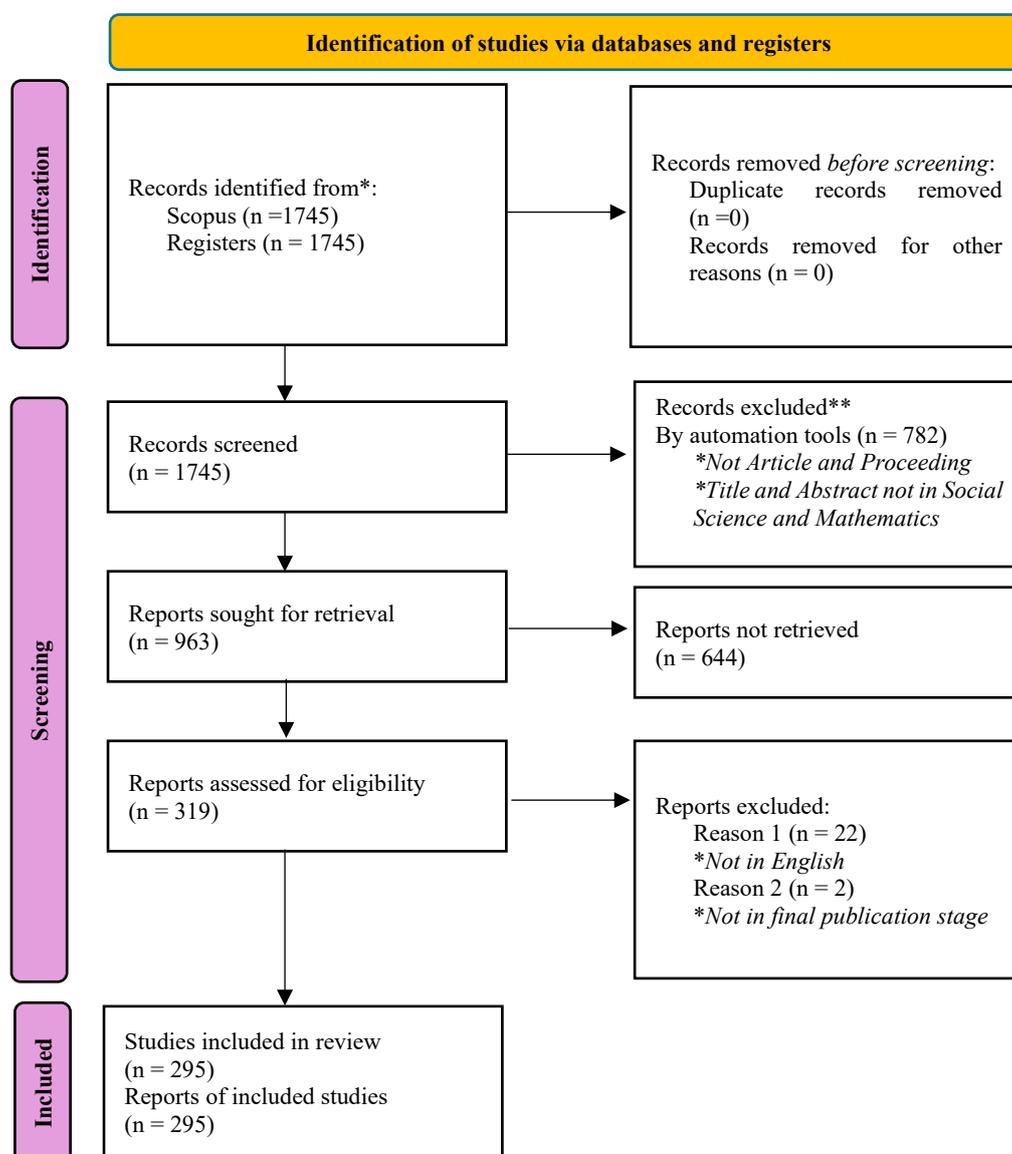


Figure 1. Flow Diagram of The Search Strategy (Page et al., 2021)

To ensure data quality and relevance, systematic inclusion and exclusion criteria were employed. Inclusion criteria were strictly limited to articles and proceedings related explicitly to blended learning in mathematics education indexed in Scopus (1999 to 2025), written in English and categorized under Social Science and Mathematics. Exclusion criteria eliminated non-English articles and proceedings, non-academic documents such as editorials, book chapters, incomplete metadata entries, and those unrelated to mathematics education. After applying these detailed screening steps, 295 relevant studies were finalized and included in the bibliometric analysis. This careful and transparent screening approach ensures reliability and accuracy in capturing the scholarly landscape of blended learning in mathematics education.

Data Cleaning, Harmonization, and Analysis

Data cleaning and harmonization are essential steps in ensuring accurate and reliable bibliometric analysis outcomes. Initially, bibliographic records extracted from the Scopus database in CSV format underwent refinement using OpenRefine to standardize author names, affiliations, and keywords. Advanced data preparation and harmonization were further conducted using biblioMagika® (Ahmi, 2024), generating indicators such as publication counts, number of authors, citation total and averages, and bibliometric indexes (h-index, g-index, m-index, Citation Sum within the h-Core). Missing or incomplete data identified through this process were manually corrected to enhance data integrity, ensuring clarity, consistency, and accuracy.

Subsequently, a structured approach was employed to examine current research focusing on important aspects such as document types, source titles, languages, subject areas, and citation metrics. Findings were categorized by publication year, authors, institutions, and countries, thus identifying major contributors and emerging trends. Additionally, thematic mapping and co-occurrence network analyses were performed using author keywords to visualize thematic clusters and reveal underlying research patterns and connections among various subfields. These analytical and visualization approaches provided comprehensive insights into the blended learning landscape in mathematics education research.

Tools

This study utilized multiple specialized software tools to conduct a systematic bibliometric analysis. Initially, Microsoft Excel was employed to organize and prepare the raw bibliometric data retrieved from Scopus, facilitating efficient sorting and structuring processes. The metadata was then standardized and harmonized using biblioMagika®, addressing inconsistencies in author names, affiliations, and country details. OpenRefine was used to enhance the clarity and consistency of author keywords. Following data preparation, VOSviewer was applied to generate visual maps illustrating keyword patterns, thematic clusters, and citation relationships. Lastly, Mendeley was employed as a reference management tool, ensuring efficient citation organization throughout the study.

Results

The following results section provides a thorough analysis of the current blended learning research in mathematics education. This analysis systematically addresses each research question, offering detailed insights into the bibliometric landscape and delivering a comprehensive overview of blended learning studies in the context of mathematics education.

Current State of Research

To address the first research question, the authors mapped the current state of research by analyzing the distribution of publications across various bibliometric indicators, including total publication output, citation

metrics, and author contributions (see Table 1). These indicators enable an assessment of productivity, scholarly influence and collaboration trends in the research domain over time. Covering the period from 1999 to 2025, the dataset comprises a total of 295 publications spanning 27 citable years, underscoring sustained scholarly engagement and continuous growth within the field. These publications were collectively authored by 895 contributing authors, highlighting extensive academic collaboration. Of these outputs, 254 papers have been cited, demonstrating notable visibility and acknowledgment within the academic community.

Table 1. Citation Metric

Main Information	Data
Publication Years	1999 - 2025
Total Publications	295
Citable Year	27
Number of Contributing Authors	895
Number of Cited Papers	254
Total Citations	3,837
Citation per Paper	13.01
Citation per Cited Paper	15.11
Citation per Year	147.58
Citation per Author	4.29
Author per Paper	3.03
Citation Sum within h-Core	3,088
h-index	28
g-index	49
m-index	1.037

Source: Generated by the author(s) using biblioMagika® (Ahmi, 2024)

In terms of academic influence, the research corpus has amassed 3,837 total citations, translating to an average of 13.01 citations per paper. The average citations per cited paper stands at 15.11, further emphasizing the ongoing scholarly relevance of cited publications. The annual citation rate averages at 147.58, reflecting steady and robust academic interest and engagement across multiple decades. At an individual contribution level, each author averages 4.29 citations, while the average number of authors per paper is 3.03, suggesting meaningful collaborative and interdisciplinary interactions among researchers.

The citation sum within the h-core is notably high at 3,088, indicating that the core set of highly cited papers significantly influences the scholarly dialogue and the direction of the field. Further bibliometric indicators reinforce the robustness and depth of the research landscape. The h-index of 28 indicates that at least 28 papers have each garnered a minimum of 28 citations, underscoring a strong balance between productivity and scholarly impact. Similarly, the g-index of 49 highlights that top publications continue to accrue citations consistently. Additionally, the m-index of 1.037 points to a steady increase in scholarly influence over time. Collectively, these metrics clearly demonstrate that blended learning research in mathematics education represents an active,

influential, and collaborative scholarly field. This body of literature has significantly contributed to the broader educational landscape, informing both theory and practice in mathematics education.

Publication Trends

To address the second research question, the authors examined publication trends in blended learning studies within mathematics education. The earliest recorded publication in the dataset appeared in 1999, marking the onset of academic interest in blended learning within mathematics education. The data in Figure 2 and Table 2 indicate that the field exhibited gradual growth initially. The most significant increase in publication output occurred between 2016 and 2023. This clear upward trajectory highlights sustained and robust scholarly attention to the field. The annual publication data identify several notable milestones in research productivity, particularly during the years 2020 (42 publications), 2022 (46 publications) and 2023 (58 publications) with 2023 marking the highest recorded output. Parallel to the rise in publication counts, citation metrics have also shown significant peaks. The highest total citation count was observed in 2020 with 715 citations, followed by substantial citations in 2022 with 568 citations and 2021 with 494 citations. These citation peaks underline the considerable scholarly influence and recognition these recent publications have garnered within the academic community. While the dataset for 2023 indicates sustained academic productivity with 58 publications and 327 citations, the observed decline in citation counts compared to previous peak years may suggest a natural temporal lag in citation accumulation or potentially reflect an emerging shift towards new research themes and methodologies within the field. Nevertheless, the overall scholarly interest and engagement remain robust.

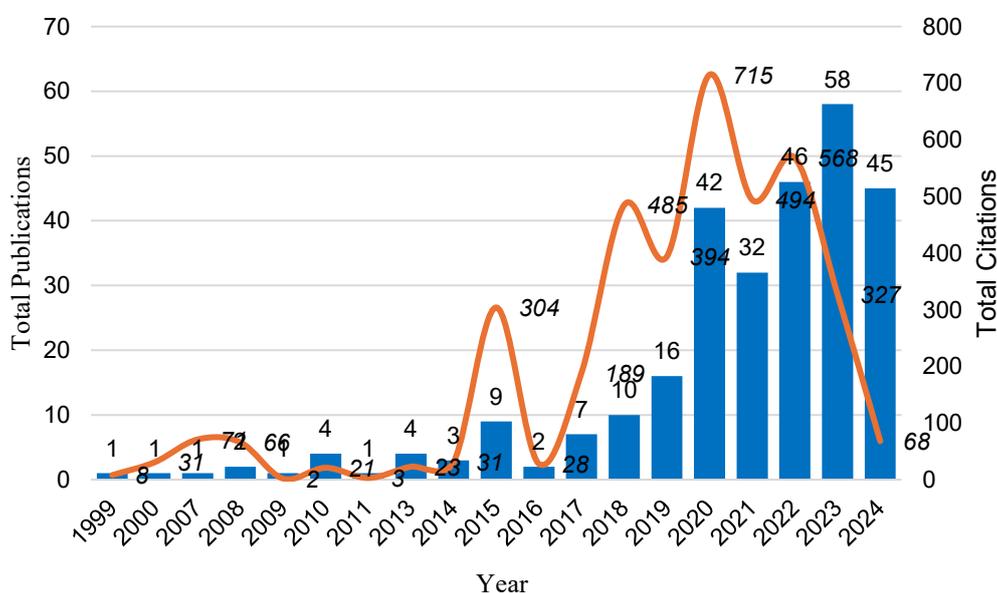


Figure 2. Total Publications and Citations by Year (Excluding the Year 2025, as Data is Only Available Up to 10 July 2025)

The consistent growth in publication numbers is accompanied by intensified scholarly collaboration, as evidenced by the increasing number of contributing authors each year. This trend demonstrates the strengthening of a global

academic community actively engaged in interdisciplinary studies that combine mathematics education with instructional design, educational technology and innovative pedagogical approaches. Bibliometric indicators including the h-index (28), g-index (49) and m-index (1.037) reinforce the strong trajectory and increasing academic influence of research in this field. In summary, the analysis underscores blended learning in mathematics education as a thriving area of scholarly inquiry, characterized by increasing publication output, strong collaborative networks, and significant academic impact. The fluctuations observed in recent citation trends highlight the dynamic nature of scholarly dissemination and emphasize the importance of ongoing monitoring and analysis to fully capture emerging research trends and priorities in this evolving field.

Table 2. Publication by Year

Year	TP	NCA	NCP	TC	C/P	C/CP	<i>h-index</i>	<i>g-index</i>	<i>m-index</i>
1999	1	4	1	8	8.00	8.00	1	1	0.037
2000	1	3	1	31	31.00	31.00	1	1	0.038
2007	1	2	1	71	71.00	71.00	1	1	0.053
2008	2	3	2	66	33.00	33.00	2	2	0.111
2009	1	5	1	2	2.00	2.00	1	1	0.059
2010	4	12	4	21	5.25	5.25	3	4	0.188
2011	1	4	1	3	3.00	3.00	1	1	0.067
2013	4	13	3	23	5.75	7.67	2	4	0.154
2014	3	8	2	31	10.33	15.50	2	3	0.167
2015	9	28	8	304	33.78	38.00	6	9	0.545
2016	2	4	2	28	14.00	14.00	2	2	0.200
2017	7	16	6	189	27.00	31.50	5	7	0.556
2018	10	32	8	485	48.50	60.63	7	10	0.875
2019	16	55	15	394	24.63	26.27	9	16	1.286
2020	42	119	42	715	17.02	17.02	16	25	2.667
2021	32	107	32	494	15.44	15.44	14	20	2.800
2022	46	131	44	568	12.35	12.91	13	21	3.250
2023	58	182	50	327	5.64	6.54	9	14	3.000
2024	45	129	26	68	1.51	2.62	4	6	2.000
Grand Total	285	857	249	3828	13.43	15.37	28	49	1.037

Notes: TP = total number of publications; NCA = number of contributing authors; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; h = h-index; g = g-index; m = m-index.

**Excluding the year 2025, as data is only available up to 10 July 2025*

Productive Authors, Institutions, and Countries

To address the third research question, the authors identified productive authors, institutions, and countries actively contributing to blended learning research in mathematics education. Table 3 highlights the most

productive authors contributing significantly to this field. Leading this group are David González-Gómez and Jin Su Jeong, both from Universidad de Extremadura who authored four highly cited publications with a total of 84 citations, averaging approximately 21 citations per publication, indicating their substantial impact and scholarly recognition within this research community. Additionally, other contributing authors include Zsolt Lavicza, Helge Fredriksen, and Dadang Juandi also made four publications respectively.

Table 3. Top 5 Most Productive Authors

Full Name	Current Affiliation	Country	TP	NCP	TC	C/P	C/CP	<i>h</i>	<i>g</i>	<i>m</i>
González-Gómez, David	Universidad de Extremadura	Spain	4	4	84	21.00	21.00	4	4	0.667
Jeong, Jin Su	Universidad de Extremadura	Spain	4	4	84	21.00	21.00	4	4	0.667
Lavicza, Zsolt	Johannes Kepler University	Austria	4	4	62	15.50	15.50	3	4	0.500
Fredriksen, Helge	The Arctic University of Norway	Norway	4	3	44	11.00	14.67	3	4	0.500
Juandi, Dadang	Universitas Pendidikan Indonesia	Indonesia	4	4	20	5.00	5.00	3	4	0.750

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; *h* = h-index; *g* = g-index; *m* = index.

Further bibliometric indicators such as h-index, g-index, and m-index enrich our understanding of these scholars' impact. For example, González-Gómez and Jeong each hold an h-index and g-index of 4, along with an m-index of 0.667 confirming their steady and sustained influence over time. This analysis highlights productive scholars whose contributions significantly influence the discourse and development of blended learning approaches in mathematics education. The insights identify key researchers actively shaping the academic conversation and directing future research trajectories in this vibrant educational field.

Next, Table 4 highlights the institutions that have actively shaped research on blended learning in mathematics education, emphasizing those with at least four scholarly publications. Universitas Pendidikan Indonesia leads notably with a total of seven publications, followed by Universidad de Extremadura, Johannes Kepler University, Universidad Nacional Autónoma de México, De La Salle University, and Open University UK, each contributing four publications. In terms of citations, Universidad de Extremadura from Spain received highest total citation (84 citations) with average of 21 citations per publication, underlining its significant impact per research output. Regarding bibliometric indices, Universitas Pendidikan Indonesia notably leads with an h-index of 5 and a g-

index of 6, reflecting consistent impact and scholarly recognition. In summary, these institutions highlight a dynamic research community, paving the way for continued innovation and impactful future research.

Table 4. Most Productive Institutions with a Minimum of Four (4) Publications

Institution Name	Country	TP	NCP	TC	C/P	C/CP	<i>h</i>	<i>g</i>
Universitas Pendidikan Indonesia	Indonesia	7	7	40	5.71	5.71	5	6
Universidad de Extremadura	Spain	4	4	84	21.00	21.00	4	4
Johannes Kepler University	Austria	4	4	62	15.50	15.50	3	4
Universidad Nacional Autónoma de México	Mexico	4	4	26	6.50	6.50	3	4
De La Salle University	Philippines	4	3	25	6.25	8.33	3	4
Open University UK	United Kingdom	4	3	4	1.00	1.33	1	2

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; *h* = h-index; *g* = g-index; *m* = index.

Further analysis reveals countries significantly contributing to this field. Figure 3 and Table 5 summarizes research productivity at the country level, highlighting nations contributing ten or more publications.

Table 5. Countries that Contributed Ten (10) or More Publications

Country	TP	NCA	NCP	TC	C/P	C/CP	<i>h</i>	<i>g</i>
Indonesia	38	124	32	330	8.68	10.31	10	18
United States	37	116	33	644	17.41	19.52	15	25
Spain	24	72	22	425	17.71	19.32	10	20
China	18	38	14	99	5.50	7.07	6	9
United Kingdom	14	41	13	286	20.43	22.00	9	14
Germany	14	32	13	237	16.93	18.23	6	14
South Africa	11	26	9	187	17.00	20.78	6	11
Malaysia	10	36	10	76	7.60	7.60	4	8
Russian Federation	10	35	10	85	8.50	8.50	5	9
Norway	10	17	9	297	29.70	33.00	7	10

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; *h* = h-index; *g* = g-index; *m* = index

Indonesia emerges as the leading contributor publishing a total of 38 articles, achieving a substantial impact with 330 citations and an h-index of 10 reflecting a consistent and influential presence within the international research community. This performance indicates not only productivity but also considerable scholarly engagement and recognition. The United States closely follows with 37 publications yet notably leads in terms of citation impact

A red cluster is centered on the concept of "blended learning" closely associated with keywords such as "online learning", "distance learning", "hybrid learning", and "e-learning". This cluster emphasizes the increasing significance of digital and hybrid educational strategies underscoring the importance of online platforms and technology-supported approaches. The presence of "pandemic" and "COVID-19" particularly highlights how recent global disruptions have accelerated the adoption of blended learning thus reinforcing its crucial role in maintaining educational continuity and addressing emerging challenges within education contexts. Another substantial thematic area represented by the green cluster revolves around "flipped classroom" closely linked with keywords such as "active learning", "attitudes", and "education". This cluster strongly highlights student-centered instructional approaches designed to actively engage learners and foster positive attitudes toward mathematics. The presence of "gamification" and "project-based learning" further suggests an emphasis on interactive, engaging pedagogies that promote deeper learner autonomy and academic achievement. The yellow cluster encompasses themes centered on "mathematics education" closely associated with keywords such as "educational technology" and "technology". This cluster underscores the strategic implementation of digital tools and technological innovation aimed at enhancing students' mathematical understanding and supporting effective teaching practices.

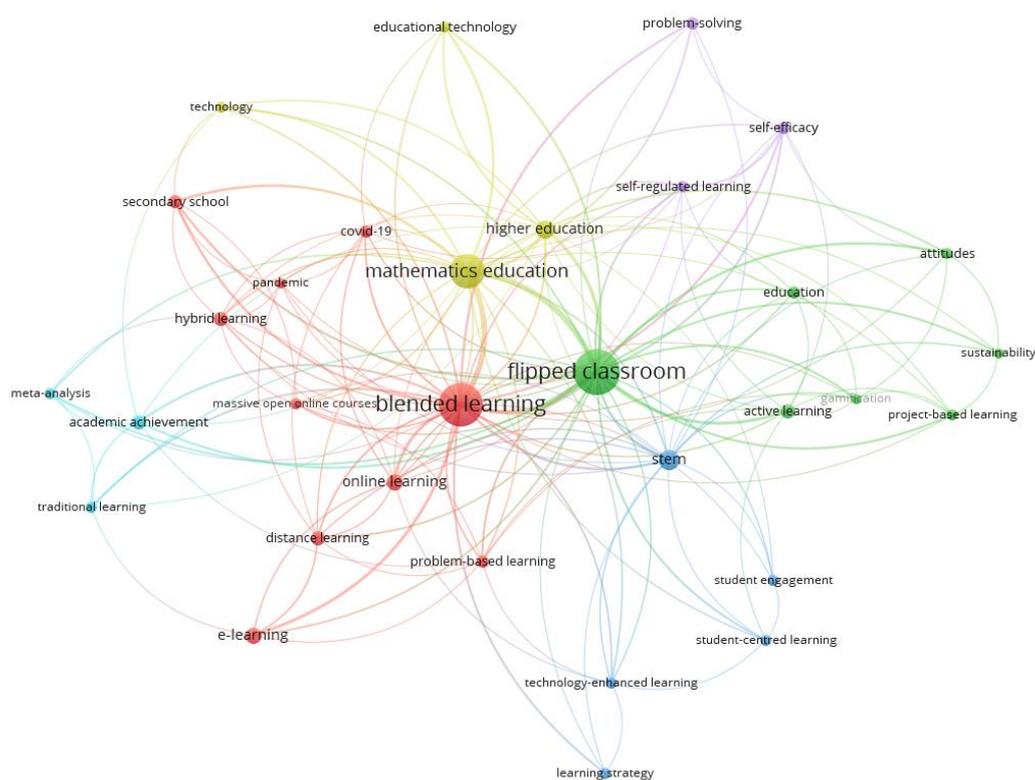


Figure 4. Co-Occurrence Network of the Author's Keywords with At Least Five Occurrences

Additionally, the blue cluster highlights the role of "STEM" education and is closely linked with "student engagement", "student-centered learning", "technology-enhanced learning", and "learning strategy". This thematic grouping emphasizes the importance of interdisciplinary integration, highlighting current educational policies and practices that prioritize the connection between mathematics and other STEM disciplines. This cluster also strongly indicates a growing research interest in innovative pedagogical approaches that leverage technology

to create engaging, student-focused, and sustainable learning environments. Moreover, the purple cluster emphasizes learner competencies highlighted by keyword of “self-efficacy” and “problem-solving”. This cluster indicates growing scholarly attention towards understanding how blended learning environments can enhance self-confidence and strengthen critical problem-solving skills which are crucial competencies for thriving in the 21st century. Collectively, the co-occurrence analysis highlights that research on blended learning in mathematics education is strongly connected to pedagogical strategies such as “project-based learning”, “problem-based learning”, “gamification”. The prominence of these themes within the network suggests their vital role in promoting effective instructional practices and reflects an ongoing commitment to engaging students actively in their own learning processes, fostering deeper mathematical reasoning and applied problem-solving skills.

Discussion

This study presents a comprehensive bibliometric analysis exploring the current landscape of blended learning research in mathematics education from 1999 to 2025 with 295 publications indexed in Scopus. The findings indicate significant scholarly growth, highlighting blended learning as a prominent instructional approach particularly within the field of mathematics education. The analysis shows a consistent upward trend in publications with the highest peak in 2023 by 58 publications reflecting rising global interest in blended learning approaches. This increase in publication numbers corresponds with the rise of educational technologies and blended learning practices particularly accelerated during the pandemic. The substantial citation peaks in 2020 with 715 citations underscore the foundational impact of key studies during periods of educational disruption, signifying the vital role blended learning has played in ensuring educational continuity and adaptation to new learning environments (Ashraf et al., 2021).

In examining prominent scholars, authors such as David González-Gómez and Jin Su Jeong have significantly shaped current educational practices in this field by their consistent scholarly contribution. Prominent institution which is Universitas Pendidikan Indonesia have emerged as key players reinforcing institutional commitments to integrating innovative blended learning approaches. These contributions reflect their growing visibility and academic engagement within the community. On an international level, countries including Indonesia and the United States lead research contributions reflecting a global recognition of blended learning's effectiveness in diverse educational contexts. Adoption of technology in education during the Fourth Industrial Revolution may led to greater implementation and research on blended learning in mathematics education (Naidoo & Reddy, 2023).

The co-occurrence analysis further identified important research themes within blended learning in mathematics education. Blended learning's as a central theme underscores its vital role in shaping modern educational practices especially during global disruptions. This highlights the adaptability and practicality of blended learning methods for ensuring educational continuity in challenging contexts (Jailani et al., 2025). The emphasis on flipped classrooms and active learning signifies an important pedagogical shift towards student-centered strategies that prioritize student autonomy and conceptual understanding. This reflects a broader pedagogical transformation from traditional teaching methods towards student-centered approaches aimed to fostering critical thinking and

active learning capabilities (Nuryadin et al., 2023). Additionally, the integration of STEM education within blended learning underscores the importance of interdisciplinary instructional methods, aligning with contemporary educational priorities aimed at equipping students to face real-world challenges (Gong et al., 2024).

Furthermore, the focus on technology-enhanced learning emphasizes the critical role of digital tools in providing interactive and personalized mathematics instruction. Selecting suitable technologies is essential to support dynamic mathematics instruction and actively engage students in exploring abstract concepts (Suripah et al., 2025). As effective technology integration aligned with instructional objectives will promote student participation, facilitates real-time assessment and personalized feedback that extends mathematical discussions beyond classroom boundaries. However, despite significant attention to digital integration, comprehensive research remains necessary to critically evaluate specific technologies effectiveness in blended learning environments (Angawi & Tasir, 2024).

The findings from the co-occurrence analysis also indicate a clear relationship between blended learning and pedagogical strategies such as project-based, problem-based, and gamification within mathematics education. As effective blended learning requires thoughtful planning, teachers must choose and integrate appropriate instructional methods based on their teaching goals, course content, and student characteristics (Yu et al., 2025). The blended project-based learning facilitates students' creative learning and product development without limitations of time and place. This approach enables students to solve problems through investigations and experiments, supported by the flexibility of space and time provided by blended learning (Suyantiningsih et al., 2023). Meanwhile, blended problem-based learning provides interactive learning environment that encourages active engagement and critical thinking as students solve problems involving mathematical concepts (Nasrullah et al., 2025). Additionally, the emergence of gamification as a significant theme indicates a growing emphasis on more engaging and interactive pedagogies within mathematics classrooms. Gamification, which integrates game-like elements into learning, makes mathematics education more enjoyable, positively influencing students' attitudes and motivation (Zhao et al., 2021). These interconnected pedagogical approaches within the blended learning framework significantly enhance student learning outcomes and experiences.

Overall, this bibliometric analysis highlights the potential of blended learning to enhance mathematics education through active learning and effective technology integration. However, several areas still require deeper exploration. Although pedagogical strategies like project-based, problem-based and gamification are widely discussed, other approaches such as task-based, role-playing, inquiry-based and case-based learning had great potential (Yu et al., 2025) but remain understudied. Future research could explore how these methods support learner autonomy and conceptual understanding in mathematics education. Additionally, although advanced technologies such as artificial intelligence and augmented reality are gaining attention in mathematics (Li & Zaki, 2024), their application within blended mathematics instruction remains limited. Further investigation of these emerging technologies could deepen our understanding of their instructional value and influence on learning outcomes. Lastly, while blended learning has been shown to improve students' problem-solving skills, there is a noticeable lack of focus on fostering higher-order thinking skills such as creativity and critical thinking. These competencies are essential for mathematics education in the 21st century and warrant more targeted research.

Conclusion and Future Research

This bibliometric analysis provides a comprehensive overview of the research landscape related to blended learning in mathematics education covering 295 publications from 1999 to 2025. Findings indicate a steady increase in scholarly interest particularly from 2016 onwards, driven significantly by the growing global demand for flexible educational solutions. Leading institution which is Universitas Pendidikan Indonesia stand out prominently with the highest total publication reflecting their pivotal roles in shaping blended learning research. Significant scholarly contributions from countries including Indonesia and the United States further underscore the global acceptance and application of blended learning methodologies in mathematics education. The co-occurrence analysis identifies core research themes such as blended learning, flipped classrooms, and mathematics education. These themes highlight the critical role of digital integration and innovative pedagogies in enhancing students' real-world competencies and academic achievement within blended mathematics instruction. Despite these insights, further research is needed to explore underrepresented pedagogical strategies within blended learning contexts. Moreover, deeper exploration into emerging technologies could significantly enhance instructional effectiveness. Future studies should explicitly address strategies for developing higher-order cognitive skills, preparing students to effectively meet 21st-century educational demands. Ultimately, this bibliometric analysis offers a solid foundation for advancing blended learning approaches in mathematics education by offering valuable insights for educators, researchers, and policymakers.

Acknowledgements

The authors would like to thank Universiti Teknologi Malaysia and the Ministry of Education Malaysia, under the HADIAH LATIHAN PERSEKUTUAN (HLP) scholarship, for their support in making this research possible.

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