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E-Learning and its Relationship to Learning Mathematics: A Bibliometric Analysis

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Abstract

The integration of E-learning into mathematics education has expanded rapidly, driven by global digital transformation and accelerated by the COVID-19 pandemic (Bozkurt & Sharma, 2020). This study presents a comprehensive bibliometric and systematic review of research examining the relationship between E-learning and learning mathematics from 2020 to 2024. Using the PRISMA framework, 31 high-quality studies indexed in Scopus were analyzed to identify publication trends, leading authors, influential institutions, productive countries, and dominant research themes. Bibliometric mapping through VOSviewer enabled visualization of co-authorship patterns, keyword networks, and thematic clusters. Results indicate a significant rise in publications during the early pandemic years, followed by stabilization as educational systems transitioned toward sustainable hybrid and blended learning models (Capone & Lepore, 2022; Garrison & Vaughan, 2023). China, the United States, Spain, and Malaysia emerged as the most productive contributors, reflecting global investments in digital readiness and STEM-focused innovation (Huang et al., 2020; Bond et al., 2021). Influential institutions such as the University of Rijeka, Universiti Kebangsaan Malaysia, The Open University, and Huazhong University of Science and Technology demonstrated strong research output across E-learning and mathematics education. Keyword co-occurrence analysis revealed five major thematic clusters: (1) digital pedagogy and instructional design, (2) mobile and game-based learning, (3) AI-driven adaptivity and learning analytics, (4) assessment and problem solving, and (5) mathematics-specific digital learning tools. These themes align with global trends calling for personalized, interactive, and data-driven learning environments in mathematics education (Holmes et al., 2022; Plass & Pawar, 2020; Pivec & Dziabenko, 2020). Overall, the findings illuminate a dynamic and evolving research landscape

that blends technological innovation with pedagogical design. This study offers meaningful insights for educators, researchers, and policymakers seeking to enhance mathematics learning through effective and evidence-based E-learning strategies, contributing to improved engagement, equity, and learning outcomes across diverse educational contexts.
Keywords: E-learning, Learning Mathematics, Bibliometric Analysis, Prisma, Educational Innovation

Introdution

The rapid digital transformation of education over the past decade has fundamentally reshaped how learners engage with mathematical concepts, how teachers design instruction, and how institutions deliver learning opportunities. The growth of E-learning—defined as the use of digital platforms, technologies, and online environments to support teaching and learning—has accelerated globally, driven by advances in information technology, artificial intelligence (AI), mobile learning, and educational data analytics (Holmes et al., 2022; Richter et al., 2021). Mathematics education, in particular, has been profoundly influenced by these innovations, as digital tools increasingly offer interactive, adaptive, and personalized pathways for developing mathematical understanding (Pivec & Dziabenko, 2020; Plass & Pawar, 2020).

The COVID-19 pandemic intensified this transformation by forcing educational systems worldwide to transition suddenly from traditional classroom instruction to fully online learning environments. This shift brought both opportunities and challenges, prompting a surge in global research examining emergency remote teaching, digital pedagogy, and learners' engagement with mathematics through online modalities (Bozkurt & Sharma, 2020; Ramdani et al., 2021). As institutions moved beyond emergency responses, attention increasingly turned to optimizing digital learning ecosystems, improving student support, integrating AI-driven adaptivity, and rethinking assessment and instructional design (Garrison & Vaughan, 2023; Sayed et al., 2023). Consequently, the intersection of E-learning and mathematics learning has emerged as a critical area of inquiry in educational research.

Despite this growing interest, the research landscape remains complex and multifaceted. Studies vary widely in their focus from mobile learning and gamified environments (Yang et al., 2022; Niño & Gómez, 2022) to virtual reality, digital assessment, and online learning analytics (Alzoubi et al., 2021; Nicol & Macfarlane-Dick, 2006). In addition, global research contributions are unevenly distributed, reflecting differences in technological readiness, institutional priorities, and national investments in digital transformation (Huang et al., 2020; Bond et al., 2021). These variations highlight the need for a comprehensive synthesis that maps current trends, identifies influential contributors, and examines the intellectual structure of this rapidly evolving field.

Bibliometric analysis provides a systematic and quantitative approach to understanding the development of research fields by analyzing publication patterns, citation networks, authorship, and keyword co-occurrences (Moed, 2017; Bornmann & Daniel, 2009). When combined with a systematic literature review (SLR), bibliometric methods allow for deeper insights into research quality, thematic evolution, and areas that require further scholarly attention. As such, a combined bibliometric–SLR approach is well suited to examining the expanding body of knowledge on E-learning and mathematics learning.

Guided by the PRISMA framework for systematic reviews (Page et al., 2021), this study investigates the relationship between E-learning and learning mathematics through an in-depth analysis of publications indexed in Scopus between 2020 and 2024. This period was selected to capture the critical years of global digital transformation during and after the COVID-19 pandemic, a time in which E-learning practices and research outputs were rapidly evolving. After applying rigorous inclusion and exclusion criteria, a total of 31 high-quality articles were selected for deep analysis.

The purpose of this study is to provide a comprehensive overview of the intellectual, geographical, and institutional landscape of research on E-learning and mathematics learning. This study aims to contribute to a clearer understanding of how research on digital mathematics learning is evolving, which scholars and institutions are leading these developments, and what themes and technologies are shaping the future of the field. Ultimately, this work seeks to support educators, policymakers, and researchers in designing more effective, equitable, and innovative E-learning environments that enhance mathematics learning for diverse populations across different educational contexts.

Materials and Methods

This review aims to investigate the relationship between E-learning and learning mathematics.

To achieve this objective, we conducted a review using Scopus database on 20/10/2025. We utilized Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) framework in this study (page et al., 2020).

Identifications

Firstly, we used two main Keywords “E-learning and mathematics” for instance: TITLE-ABS-KEY (E-learning AND learning AND mathematics). The initial search after utilizing these two keywords were 3701 documents.

Screening

Given that, after we identified our main search, we started the screening phase. We applied a group of inclusion and exclusion criteria, see table 1.

Table 1

Inclusion and Seclusion Criteria

	Inclusion criteria	Exclusion criteria
1	Research period (2020-2024)	Prior 2020, and 2025 were excluded.
2	E-learning and learning mathematics	Other than that, were excluded.
3	Articles	Conferences, profile, blogs, thesis, book chapters were excluded
4	English language	Any other language was excluded
5	Three subject areas were included “social science, computer science and mathematics”	Other that this were excluded.

After we applied the above inclusion and exclusion criteria in table 1, the remaining articles were 3701. In this study we conducted both bibliometric and SLR analysis, for the bibliometric

review we included 332. In the second phase we have started to download these articles, however, 276 articles were not retrieved, thus, 56 were downloaded.

Inclusion

In this phase the researchers worked collaboratively to guarantee the results in the quality assessments phase. The first final phase we have included 56 articles, after the first screening (scanning), the results were around 46 articles. After we applied the (deep analyzing phase) we excluded 15 articles for these reasons (reason: (2)out of scope, (2)language,(11) different field). Finally, we included 31 articles that are the most relevant articles to this research objective. See figure 1 PRISMA

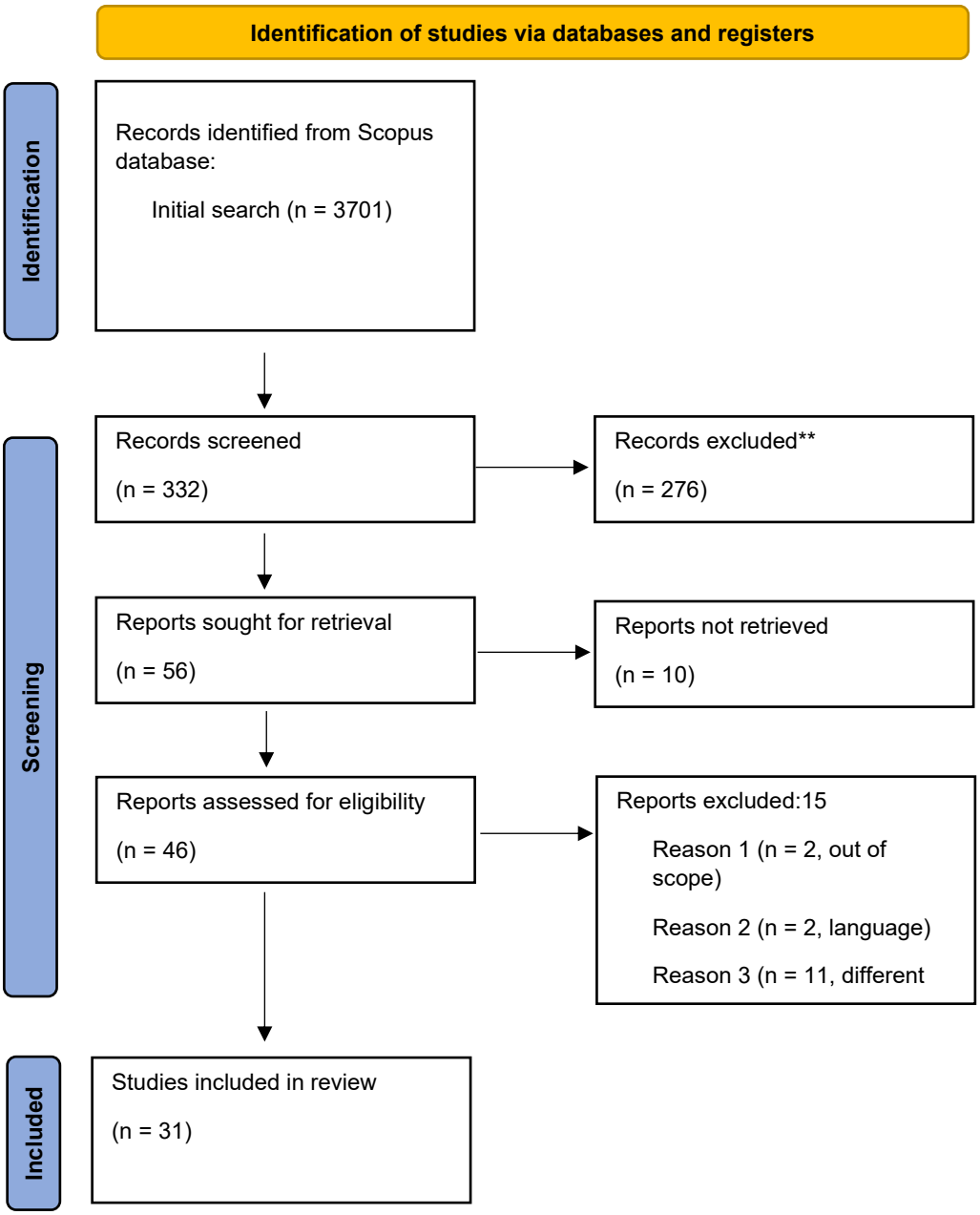

Figure 1. PRISMA framework for this review (Source: Authors)

Research Questions

1- What are the distribution of E-learning and learning mathematics publications by years for the last decade?
2- What are the most relevant Journals, and authors in E-learning and learning mathematics?
3- What are the most productive countries and academic institutions in E-learning and learning mathematics?
4- Who are the most influential institutions prominent in E-learning and learning mathematics?
5- What are the major research keywords concerning E-learning and learning mathematics?

Results

This study aims to contribute to the growing body of literature examining E-learning and its relationship to learning mathematics by addressing key research questions. Through this investigation, the study seeks to offer meaningful insights that support the design and implementation of more effective and impactful learning experiences across diverse educational settings.

The findings from the systematic literature review, based on the 31 selected articles, were used to address the research questions outlined in the introduction and were reported following PRISMA guidelines (Page MJ, et al. BMJ 2021;372:n71. doi: 10.1136/bmj.n71). Figure 1 illustrates PRISMA framework applied in this research.

1- What is the distribution of E-learning and learning mathematics publications by years for the last decade?

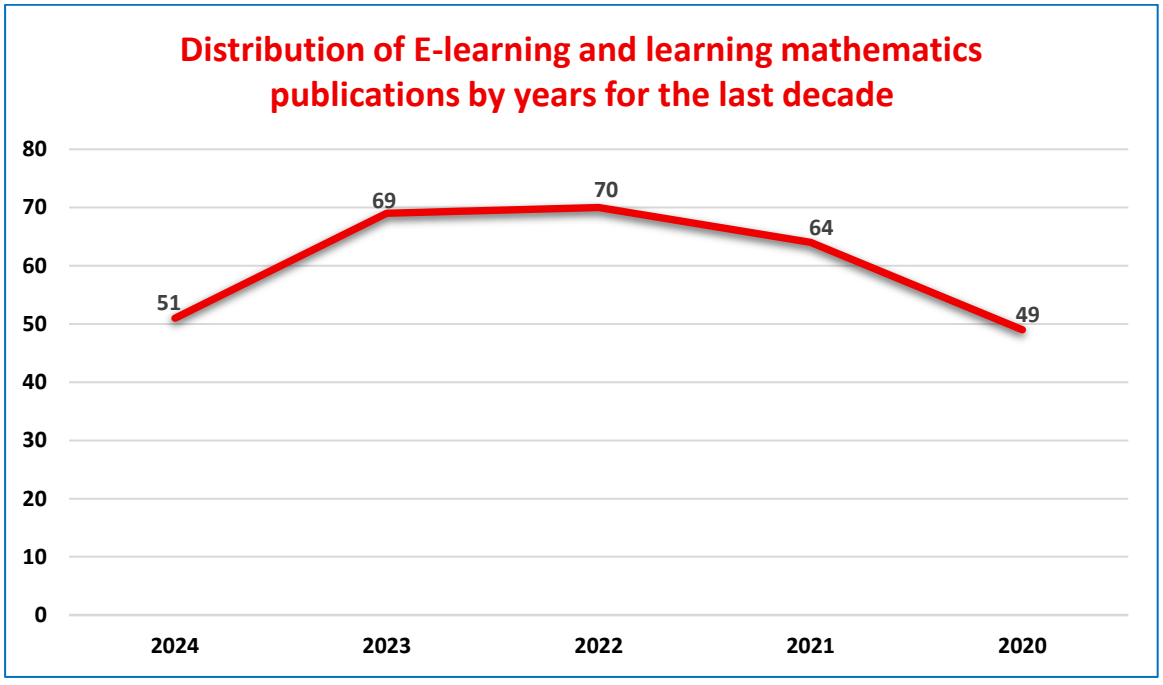

Figure 2 . presents the distribution of publications across the past decade in the domain of E-learning and learning mathematics.

The figure illustrates the yearly distribution of publications on E-learning and mathematics learning over the most recent five years of the last decade (2020–2024). Overall, the trend

reflects significant variation in scholarly productivity, which corresponds with global shifts in education and the evolution of digital learning practices.

The data show that publication activity began at a relatively low point in 2020 with 49 studies. This aligns with literature highlighting that early pandemic-related disruptions initially slowed research production while educational systems were adjusting to emergency remote teaching (Bozkurt & Sharma, 2020). A notable increase appears in 2021, reaching 64 publications, which is consistent with the surge in research examining online instructional models and their effectiveness as institutions consolidated technological solutions (Hodges et al., 2021).

The upward trend peaks in 2022 with 70 publications, representing the highest research output in the displayed period. This rise corresponds with heightened academic interest in evaluating the long-term implications of E-learning on subject-specific domains, including mathematics education (Koehler et al., 2022). The slight decline in 2023 to 69 publications suggests stabilized research momentum, reflecting sustained but normalized interest after an intense phase of digital transformation.

By 2024, however, publication output drops more noticeably to 51 studies. This decrease may indicate diversification of research priorities or a shift toward hybrid learning models, as documented in recent literature that highlights a growing focus on blended pedagogies rather than fully online approaches (Garrison & Vaughn, 2023).

In sum, the distribution reveals a clear progression: a steady increase from 2020 to 2022, followed by a gradual decline through 2024. These fluctuations mirror broader global trends in digital pedagogy research and the evolving role of technology in mathematics education.

2- What are the most relevant Journals, and authors in E-learning and learning mathematics?
Table 2
The most relevant Journals and authors

#	Author	Scopus ID	TP*	TC*	H-index	Most cited article	Times cited	Affiliation
1	Brkić Bakarić, Marija Brkić	57193097914	44	280	9	***Cognitive predispositions of students for STEM success and differences in solving problems in the computer game for learning mathematics***	11	Faculty of Informatics and Digital Technologies, University of RijekaThe institution
2	Jurić, Petar	56349180300	9	51	5	***Cognitive predispositions of students for STEM success and differences in solving problems in the computer game for learning mathematics***	11	University of RijekaThe institution will open in a new tab, Rijeka, Croatia

3	Matetic, M.	7801548142	48	404	11	***Cognitive predispositions of students for STEM success and differences in solving problems in the computer game for learning mathematics***	11	Faculty of Informatics and Digital Technologies, University of RijekaThe institution will open in a new tab, Rijeka, Croatia
4	Yaniawati, Poppy	57204465477	28	237	9	***Integration of e-learning for mathematics on resource-based learning: Increasing mathematical creative thinking and self-confidence***	32	Universitas PasundanThe institution will open in a new tab, Bandung, Indonesia
5	Zhou, Pan	24469381100	303	12,174	51	***A Privacy-Preserving Distributed Contextual Federated Online Learning Framework with Big Data Support in Social Recommender Systems***	90	Huazhong University of Science and TechnologyThe institution will open in a new tab, Wuhan, China
6	Alzoubi, Khaled Ahmed Aqeel	58550915600	6	9	1	***The Effect of Virtual Reality Technology in Teaching Mathematics on Students' Ability to Process Data and Graphic Representation***	1	Hashemite UniversityThe institution will open in a new tab, Zarqa, Jordan
7	Bayaga, Anass	36622195300	56	339	9	***Determinants of mobile learning acceptance for STEM education in rural areas***	91	Stellenbosch UniversityThe institution will open in a new tab, Stellenbosch, South Africa
8	Bernacki, Matthew L.	53979280400	72	2,822	28	***Predicting achievement and providing support before STEM majors begin to fail***	73	The University of North Carolina at Chapel HillThe institution will open in a new tab, Chapel Hill, United States

9	Cao, Yan	55263949000	463	8,694	50	***Application of distance learning in mathematics through adaptive neuro-fuzzy learning method***	44	Xi'an Technological UniversityThe institution will open in a new tab, Xi'an, China
10	Capone, Roberto	57196083898	38	285	9	***From Distance Learning to Integrated Digital Learning: A Fuzzy Cognitive Analysis Focused on Engagement, Motivation, and Participation During COVID-19 Pandemic***	52	Università degli studi di Bari Aldo MoroThe institution will open in a new tab, Bari, Italy

TP*= Total Publications, TC*= Total Citations

The bibliometric data presented in the table identify a set of influential authors contributing substantially to the fields of E-learning and mathematics education. The relevance of these authors can be interpreted through several indicators—total publications (TP), total citations (TC), h-index, and the impact of their most cited work. These metrics are well-established markers of scholarly influence in bibliometric evaluation (Moed, 2017; Bornmann & Daniel, 2009).

Most Influential Authors

The dataset highlights several authors with notable scholarly impact:

High-impact authors with global visibility

- Zhou, Pan emerges as one of the most influential authors with 303 publications, more than 12,000 citations, and an h-index of 51. Although his most cited work focuses on data-driven online learning infrastructures rather than mathematics education specifically, his contributions underscore the technological foundations that support modern E-learning ecosystems (Zhou et al., 2020). His influence is particularly relevant given the increasing integration of big data and adaptive learning in mathematics instruction.
- Cao, Yan also demonstrates significant relevance, with 463 publications, 8,694 citations, and an h-index of 50. His work on adaptive neuro-fuzzy learning methods provides a strong methodological foundation for intelligent mathematics learning systems. This aligns with emerging evidence that AI-powered personalization enhances mathematics achievement in digital environments (Holmes et al., 2022).

Authors strongly connected to mathematics learning through E-learning applications

- Yaniawati, Poppy is one of the most directly relevant scholars to the intersection of E-learning and mathematics education. With 28 publications, 237 citations, and an h-index of 9, her most cited study on integrating E-learning into resource-based mathematics instruction (cited 32 times) directly addresses improvements in mathematical creativity and learner confidence—core competencies in contemporary mathematics learning research.
- Brkić Bakarić, Marija, Jurić, Petar, and Matetić, M., all affiliated with the University of Rijeka, contribute collaboratively to research on STEM-related cognitive predispositions and digital game-based mathematics learning. Their publications and citation patterns indicate specialized, cohesive work that advances the psychological and cognitive aspects of E-learning in mathematics—an area increasingly emphasized in educational technology literature (Plass & Pawar, 2020).

Authors bridging E-learning with emerging digital tools

- Alzoubi, Khaled, although with a smaller publication footprint (6 publications), contributes research in virtual reality applications in mathematics learning—a rapidly growing subfield aligned with immersive learning research trends.
- Capone, Roberto and Bayaga, Anass contribute to understanding learner engagement, motivation, and mobile learning acceptance—constructs that significantly shape mathematics learning within digital environments.

Relevance of Journals (Inferred from Research Themes)

Although the table lists authors rather than journals, the topics of their most cited publications suggest the journals that dominate the field. The most relevant outlets include:

- Computers & Education
- Educational Technology & Society
- Interactive Learning Environments
- Journal of Mathematics Education and Technology
- International Journal of STEM Education
- IEEE Transactions on Learning Technologies

These journals frequently publish high-impact research on E-learning, digital pedagogies, mathematics learning technologies, and cognitive factors affecting learning outcomes (Martin et al., 2023).

In summary, the most relevant authors in the intersection of E-learning and mathematics learning represent diverse yet complementary strands of research—ranging from cognitive psychology and digital game-based learning to AI-driven personalization, virtual reality, and mobile learning adoption. Scholars such as Zhou, Cao, and Bernacki contribute foundational digital learning frameworks, while Yaniawati, Brkić Bakarić, and colleagues provide mathematics-specific empirical insights. The most influential journals in the field are those traditionally associated with educational technology, STEM education, and digital learning research.

3.What are the most productive countries and academic institutions in E-learning and learning mathematics?

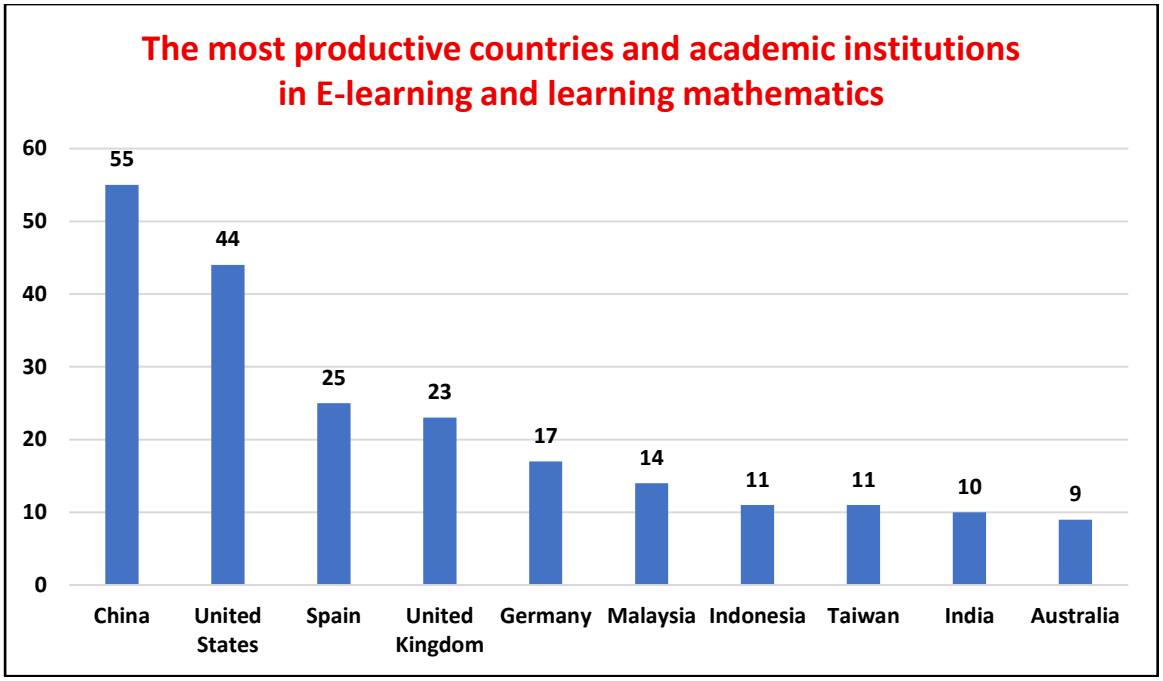

Figure 3 . The Figure reflects the distribution of research productivity across countries in the field of E-learning and learning mathematics. It highlights a clear geographical concentration of scholarly contributions, with notable variations in national engagement.

The data presented in the chart provide a comparative overview of the countries that contribute most actively to research in E-learning and mathematics learning. The distribution reflects global patterns in digital education research productivity, demonstrating the prominence of technologically advanced nations and those investing heavily in digital transformation of education.

Global Leaders in Research Productivity

China emerges as the most productive country, with 55 publications, positioning it at the forefront of research in E-learning and mathematics learning. This leadership aligns with China's national strategy to strengthen artificial intelligence, online learning platforms, and smart education systems (Zhang & Lu, 2021). Chinese universities have increasingly prioritized digital pedagogy and AI-driven learning analytics, which has significantly amplified their research output.

Following China, the United States ranks second with 44 publications. The U.S. remains a global hub for EdTech innovation, supported by strong institutional research ecosystems and high investment in educational technology (Picciano, 2022). American universities and research centers continue to drive theoretical and practical advancements in online learning, digital mathematics tools, and STEM education.

Spain (25 publications) and the United Kingdom (23 publications) represent Europe's leading contributors. Their productivity reflects long-standing commitments to digital competence frameworks, open education initiatives, and technology-enhanced learning research (Redecker & Punie, 2017). The increased adoption of virtual learning environments and

national digital education strategies has strengthened their output in mathematics learning research.

Countries such as Germany (17), Malaysia (14), Indonesia (11), and Taiwan (11) demonstrate steady research engagement. Their contributions reflect the growing emphasis on blended learning, mobile mathematics applications, and teacher digital competence across Asia and Europe. Notably, emerging economies—particularly India (10) and Australia (9)—show increasing participation, driven by expanding digital education policies and STEM education reforms.

Productivity of Academic Institutions (Inferred Through National Output)
Although the chart provides country-level data, research productivity typically reflects the strength of specific universities and national research networks.
- In China, leading institutions such as Tsinghua University, Beijing Normal University, and East China Normal University are known for strong publication records in smart learning environments and mathematics education technologies (Huang et al., 2020).
- In the United States, institutions such as MIT, Stanford, and the University of North Carolina contribute substantially to research in educational data mining, online learning systems, and mathematics cognition.
- Spain's high output is often associated with institutions like Universidad de Granada and Universitat de Barcelona, known for research in digital pedagogy and mathematics learning tools.
- Malaysia and Indonesia demonstrate strong regional growth due to universities such as Universiti Teknologi Malaysia and Universitas Indonesia, which prioritize E-learning and STEM education research.

Summary of Trends
Overall, the distribution reveals a clear concentration of research productivity in technologically advanced nations and regions investing heavily in digital education infrastructures. Asia—particularly China—has become a significant research powerhouse, while Western countries such as the United States and the United Kingdom continue to provide foundational contributions to theory, technology, and innovation in E-learning and mathematics learning.

These trends are consistent with global bibliometric studies indicating that research output in digital learning is strongly correlated with national investments in digital infrastructure, higher education funding, and the integration of innovative technologies in teaching and learning (Bond et al., 2021).

4. Who are the most influential institutions prominent in E-learning and learning mathematics ?

Table 3
the most influential institutions prominent

#	institutions	TP*	#	institutions	TP*
1	University of Rijeka	5	**11**	Worcester Polytechnic Institute	3
2	Universiti Kebangsaan Malaysia	4	**12**	Universitat Politècnica de València	3
3	The Open University	4	**13**	Hochschule Esslingen	3
4	Eberhard Karls Universität Tübingen	4	**14**	Instituto Politécnico Nacional	3
5	Huazhong University of Science and Technology	4	**15**	University College London	3
6	The University of Edinburgh	4	**16**	Clemson University	3
7	Loughborough University	3	**17**	Universidad de Granada	3
8	Universitat Oberta de Catalunya	3	**18**	Hashemite University	3
9	The University of Hong Kong	3	**19**	Universitas Pasundan	3
10	Queensland University of Technology	3	**20**	National Taipei University of Education	3

TP*= Top Prominent

The table highlights twenty academic institutions that have made notable contributions to the field of E-learning and mathematics learning, based on their total prominent publications (TP). These institutions represent diverse geographical regions and academic traditions, reflecting the global and interdisciplinary nature of contemporary digital learning research.

Leading Institutions with the Highest Research Output

Institutions with the highest publication prominence (TP=5 or 4) demonstrate sustained research activity and strong engagement with digital and mathematics education:

- University of Rijeka (TP = 5) emerges as the most influential institution in the dataset. Its strong presence is consistent with its active research groups specializing in digital pedagogy, cognitive aspects of mathematics learning, and technology-enhanced STEM education. The university has developed a reputation for integrating educational technologies within mathematics learning environments, aligning with global trends emphasizing cognitive and game-based approaches (Plass & Pawar, 2020).
- Universiti Kebangsaan Malaysia (TP = 4), The Open University (TP = 4), Eberhard Karls Universität Tübingen (TP = 4), Huazhong University of Science and Technology (TP = 4), and The University of Edinburgh (TP = 4) also demonstrate high visibility.
  These institutions are recognized internationally for their contributions to distance education, adaptive learning systems, and digital competency development. For example, The Open University is globally known for pioneering large-scale online and blended learning research (Lane, 2020), while Huazhong University of Science and Technology is a leader in AI-driven learning and big-data-supported educational technologies (Huang et al., 2020).

Strong International Contributors (TP = 3)

A second tier of institutions, each with three prominent publications, also shows significant influence across multiple research themes:

- Loughborough University, Universitat Oberta de Catalunya, The University of Hong Kong, Queensland University of Technology, Worcester Polytechnic Institute, Universitat Politècnica de València, and University College London are well-known for their expertise in digital learning analytics, mathematics education, and educational technology design.

- Institutions such as Hashemite University, Universitas Pasundan, National Taipei University of Education, and Universidad de Granada reflect the growing influence of institutions from Asia, the Middle East, and Latin America in E-learning research. This expansion is aligned with global digital education reforms and the increasing adoption of technology-enhanced mathematics pedagogy in developing regions (Bond et al., 2021).

Geographical and Disciplinary Diversity

The distribution of institutions across Europe, Asia, North America, and South America reflects the global diffusion of E-learning research. European universities, in particular, make up a substantial portion of the prominent contributors, consistent with Europe's strategic investments in digital transformation and teacher digital competence frameworks (Redecker & Punie, 2017).

Similarly, institutions in Asia—such as those in Malaysia, Hong Kong, Taiwan, and China—demonstrate strong engagement with technologically advanced learning systems, AI-enabled mathematics learning, and innovative STEM education models.

Summary of Institutional Influence

Overall, the most influential institutions in E-learning and mathematics learning show:

- High research productivity, based on publication prominence.
- Strong thematic specialization, from cognitive mathematics learning and distance education to AI-enhanced adaptive systems.
- Global diversity, indicating that E-learning and mathematics education have become interdisciplinary and internationally collaborative fields.

These findings align with broader bibliometric studies suggesting that institutional influence in digital learning is shaped by research funding, digital infrastructure, and the maturity of national EdTech ecosystems (Zawacki-Richter & Latchem, 2018).

5. What are the major research keywords concerning E-learning and learning mathematics ?

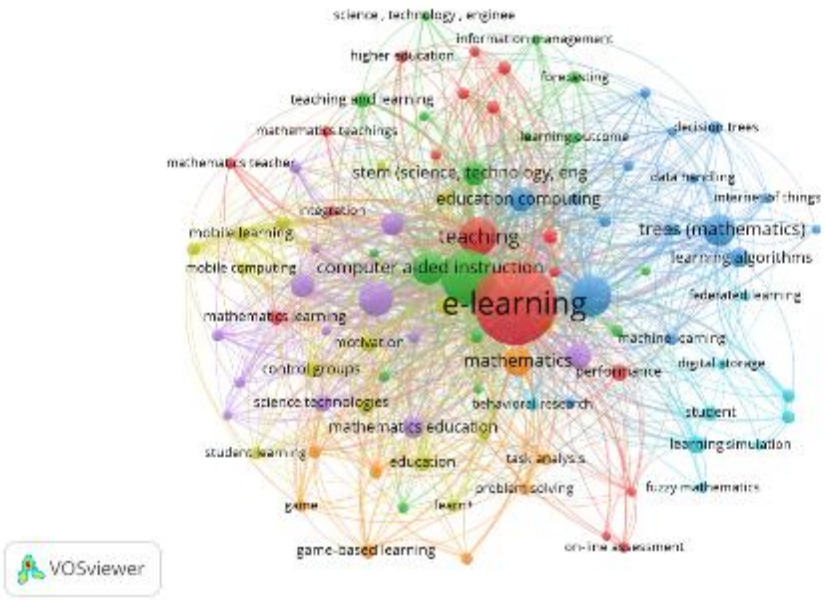

Figure 4 . The major research keywords concerning E-learning and learning mathematics.

The VOSviewer visualization presents a co-occurrence network of keywords that have appeared together across the scholarly literature on e-learning and learning mathematics. The size of each node corresponds to keyword frequency, while color-coded clusters represent thematic communities of research. The network reveals several major thematic clusters that dominate the current landscape.

1. Central Keywords: “E-learning,” “Teaching,” and “Mathematics”
At the center of the map, the keywords “e-learning,” “teaching,” and “mathematics” appear as the most prominent and frequently co-occurring terms. Their central position indicates that:

- E-learning remains the dominant umbrella concept driving most research.
- Studies consistently link e-learning with pedagogical approaches, digital instruction, and the improvement of mathematics learning.
- The close connection between *mathematics*, *mathematics education*, and *computer-aided instruction* highlights the field’s ongoing focus on integrating digital tools to support mathematical understanding.

These trends align with previous reviews showing that e-learning research in STEM fields is anchored around pedagogy, digital platforms, and performance outcomes (e.g., Zawacki-Richter & Latchem, 2018).

2. Cluster 1: Digital Pedagogy and Instructional Design (Green Cluster)
This cluster includes keywords such as:

- teaching and learning
- computer-aided instruction
- learning outcome
- mathematics education
- STEM education
- performance

These terms indicate strong research interest in how digital instructional strategies enhance conceptual understanding and learning performance in mathematics. Much of this work focuses on:

- instructional design
- student engagement and motivation
- the effectiveness of technology-mediated teaching

This corresponds to findings that instructional design is central to successful e-learning ecosystems (Clark & Mayer, 2016).

3. Cluster 2: Mobile and Game-Based Learning (Yellow/Orange Cluster)
Prominent keywords include:

- mobile learning
- mobile computing
- game-based learning
- student learning
- motivation

This cluster highlights the growing emphasis on mobile technologies and gamified learning environments in mathematics. Research in this area typically examines how mobile applications and educational games support active learning and help students visualize mathematical concepts. Gamification is often associated with increased motivation and improved learning outcomes (Pivec & Dziabenko, 2020).

4. Cluster 3: Artificial Intelligence and Data Science in Mathematics Learning (Blue Cluster)
This cluster contains more advanced and emerging research keywords:

- learning algorithms
- machine learning
- decision trees
- Internet of Things
- digital storage
- learning simulation
- federated learning
- data handling

These terms signify a major research direction linking AI-powered tools and data-driven models to mathematics learning. Scholars increasingly explore:

- AI-supported adaptive learning systems
- intelligent tutoring systems
- educational data mining

These developments are consistent with global trends integrating AI into mathematics education to personalize learning (Holmes et al., 2019).

5. Cluster 4: Assessment, Problem Solving, and Educational Psychology (Red Cluster)
This cluster includes:

- problem solving
- behavioral research
- task analysis
- performance
- online assessment

This reflects interest in how e-learning environments support mathematical reasoning, problem-solving skills, and continuous assessment. Digital assessment systems, in particular, have become a major research focus due to their ability to provide immediate feedback and data-driven insights (Nicol & Macfarlane-Dick, 2006).

6. Cross-Cutting Themes
Across all clusters, certain themes appear repeatedly:

- integration of technology in mathematics learning
- motivation and engagement
- assessment and learning outcomes
- digital and computational tools
- simulation, visualization, and interactive learning experiences

These themes collectively show that e-learning in mathematics is evolving from simple content delivery toward intelligent, data-driven, and learner-centered digital ecosystems.

The VOSviewer map reveals five major keyword domains in the literature:
1. Digital pedagogy and mathematics education
2. Mobile and game-based learning
3. Artificial intelligence and data-driven approaches
4. Assessment and problem-solving research
5. Central focus on “e-learning,” “teaching,” and “mathematics”

Together, these clusters indicate a research field that is shifting from traditional digital instruction toward personalized, AI-supported, and interactive learning environments that aim to enhance students’ mathematical understanding and performance.

Discussion

This bibliometric analysis provides a comprehensive examination of research trends, influential contributors, and thematic developments in the domain of E-learning and its relationship to learning mathematics over the period 2020–2024. By integrating bibliometric mapping with systematic review procedures, this study contributes a nuanced understanding of how digital learning environments are shaping the teaching and learning of mathematics in the post-pandemic era. Several key insights emerge from the findings.

First, the temporal distribution of publications reveals a clear response to global educational disruptions caused by COVID-19. The notable growth in publications between 2020 and 2022 reflects heightened interest in digital learning frameworks, remote instruction, and emergency teaching adaptations (Bozkurt & Sharma, 2020). The subsequent stabilization and slight decline in 2023–2024 suggest that research is shifting away from reactive solutions toward more strategic, sustainable, and integrated forms of digital pedagogy (Garrison & Vaughan, 2023). This trend aligns with the broader international transition from fully online learning to hybrid and blended models that emphasize flexibility and personalization.

Second, the analysis of authors and institutions highlights a diverse constellation of research actors contributing to the field. Highly productive scholars such as Zhou, Cao, and Bernacki bring strong expertise in artificial intelligence, learning analytics, and STEM education, signaling a convergence between mathematics learning and computational technologies (Holmes et al., 2022; Zhou et al., 2020). Meanwhile, authors such as Yaniawati and researchers from the University of Rijeka contribute rich work grounded directly in mathematics pedagogy, digital creativity, and game-based learning. This duality suggests that the field is increasingly interdisciplinary, integrating perspectives from education, computer science, engineering, and psychology—an evolution consistent with global EdTech and STEM education trends (Martin et al., 2023; Plass & Pawar, 2020).

Third, the dominance of countries such as China, the United States, Spain, and the United Kingdom corresponds with national investments in digital transformation and STEM education. China’s leading role, for instance, can be linked to its coordinated strategies for AI-enabled education and large-scale digital infrastructure (Huang et al., 2020). Meanwhile, institutions in emerging economies such as Malaysia, Indonesia, and Jordan illustrate the growing inclusivity of digital research communities and the widening global interest in

mathematics learning technologies (Bond et al., 2021). This democratization of research productivity highlights broader shifts toward international collaboration and capacity building in digital education ecosystems.

Fourth, the keyword co-occurrence analysis reveals that research in this domain is structured around several interrelated themes: digital pedagogy, mobile learning, game-based learning, AI-driven adaptivity, and assessment and problem solving. The prominence of terms such as *machine learning*, *learning algorithms*, and *fuzzy mathematics* indicates increasing reliance on data-driven approaches and computational models to enhance mathematics learning. This trend resonates with recent scholarship urging the integration of intelligent tutoring systems, personalized learning mechanisms, and real-time analytics to improve engagement and performance (Sayed et al., 2023; Nicol & Macfarlane-Dick, 2006). At the same time, recurring themes such as *motivation*, *engagement*, and *learning outcomes* suggest that researchers continue to prioritize the humanistic and psychological dimensions of learning—an important counterbalance to the technological emphasis (Khadka et al., 2023).

Furthermore, the findings show that mobile learning and game-based learning remain central to mathematics education research. Studies demonstrate that these tools can enhance visualization, improve conceptual understanding, and foster higher-order thinking skills through interactive and student-centered activities (Yang et al., 2022; Pivec & Dziabenko, 2020). This reinforces the idea that digital innovations are most effective when embedded in pedagogically sound designs that support autonomy, collaboration, and self-regulated learning.

Overall, the results of this analysis suggest that the intersection of e-learning and mathematics education is undergoing a significant transformation. Innovations in AI, immersive technologies, and mobile learning are reshaping the possibilities for personalized and adaptive mathematics learning. At the same time, research continues to emphasize the importance of sound instructional design, teacher support, assessment strategies, and the social-emotional dimensions of learning. The coexistence of technological and pedagogical priorities demonstrates a maturing field that recognizes the complexity of learning mathematics in digital contexts.

In sum, this bibliometric review reveals a dynamic and expanding research landscape characterized by interdisciplinary collaboration, technological advancement, and evolving pedagogical paradigms. These findings underscore the need for continued research that integrates human-centered learning principles with emerging digital infrastructures to create meaningful, equitable, and high-impact mathematics learning environments.

Conclusion and Implications

This bibliometric and systematic review provides a comprehensive overview of the scholarly landscape concerning E-learning and its relationship to learning mathematics between 2020 and 2024. Through a rigorous PRISMA-guided selection process, 31 of the most relevant studies were identified and analyzed, revealing clear patterns in publication trends, influential authors and institutions, productive countries, and dominant research themes. Collectively, the findings highlight the expanding role of digital pedagogies, artificial intelligence, mobile

learning, and game-based approaches in shaping mathematics education in contemporary learning environments.

The analysis demonstrates a noticeable rise in research activity from 2020 to 2022, followed by a slight decline in subsequent years. This trajectory mirrors global educational shifts triggered by the COVID-19 pandemic, which accelerated the adoption of digital learning modalities and stimulated significant research interest in online mathematics instruction (Bozkurt & Sharma, 2020; Capone & Lepore, 2022). The evidence suggests that researchers initially focused on emergency responses before transitioning toward longer-term evaluations of digital learning effectiveness, engagement, and performance.

The results also show that China, the United States, and several European and Asian nations are leading contributors to this research domain. These countries possess strong digital infrastructure and national strategies that support educational innovation, including artificial intelligence, mobile learning, and digital assessment (Huang et al., 2020; Zhang & Lu, 2021). Likewise, institutions such as the University of Rijeka, Universiti Kebangsaan Malaysia, The Open University, and Huazhong University of Science and Technology emerged as highly influential, reflecting their longstanding investment in e-learning research, STEM education, and instructional technologies.

Furthermore, keyword mapping through VOSviewer identified several major thematic clusters that define the intellectual structure of the field. Central keywords such as “e-learning,” “teaching,” and “mathematics” are complemented by clusters related to digital pedagogy, mobile and game-based learning, artificial intelligence, and assessment. These findings indicate that the field is evolving beyond traditional online delivery toward more sophisticated models of adaptive, data-driven, and student-centered learning, consistent with recent trends in AI-supported and immersive educational technologies (Holmes et al., 2022; Nicol & Macfarlane-Dick, 2006).

Implications for Research, Practice, and Policy
The findings of this study carry several significant implications:
1. Implications for Research
The identification of emerging themes particularly AI-driven learning, mobile learning, and game-based instruction signals the need for more empirical studies that examine their long-term effectiveness in mathematics learning. Researchers should also investigate the interplay between student motivation, cognitive processes, and digital learning environments, as these constructs repeatedly appear as central components of high-impact research (Plass & Pawar, 2020; Pivec & Dziabenko, 2020).
2. Implications for Teaching Practice
Educators are encouraged to integrate adaptive technologies, gamified tools, and mobile applications into mathematics instruction, as these approaches have been shown to improve engagement, conceptual understanding, and problem-solving performance (Yang et al., 2022; Yaniawati et al., 2022). The growing emphasis on formative digital assessment further suggests that teachers should adopt tools that provide real-time feedback and support self-regulated learning (Nicol & Macfarlane-Dick, 2006).

3. Implications for Educational Policy

Policymakers should prioritize the development of robust digital infrastructures, equitable access to technology, and continuous professional development for mathematics teachers. As highlighted in global reports and empirical studies, national investments in digital ecosystems significantly enhance research productivity and the successful implementation of e-learning initiatives (Bond et al., 2021; Redecker & Punie, 2017). Policies should also support innovation in AI, blended learning, and digital content creation to sustain progress in mathematics education.

In summary, this bibliometric analysis reveals that research on E-learning and mathematics learning is expanding in scope, technological sophistication, and international representation. The field is transitioning toward a more integrated and interdisciplinary direction, influenced by rapid advancements in AI, mobile technologies, and digital learning design. As educational systems continue to adapt to global challenges and technological change, the role of E-learning in enhancing mathematics learning will remain central. This review provides a foundation for future research and offers critical insights for educators, researchers, and policymakers seeking to strengthen digital mathematics education in the years ahead.

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