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Mapping the Landscape of Digital Pedagogies in Mathematics Education: A Bibliometric Study

Mohamad Ikram Zakaria [1*], Mohd Fahmi Adnan [2], Sharifah Osman [3], Najua Syuhada Ahmad Alhassora [4], Nurul Hazreen Hanafi [5], Nurul Rabiatul Adawiyah Suhaimee [6]

[1] Faculty of Educational Sciences and Technology, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia, 0000-0002-2171-8279
[2] Faculty of Educational Sciences and Technology, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia, 0000-0001-8724-6975
[3] Faculty of Educational Sciences and Technology, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia, 0000-0003-2896-9377
[4] Faculty of Educational Sciences and Technology, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia, 0000-0001-6109-6040
[5] Faculty of Educational Sciences and Technology, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia, 0009-0007-2061-069X
[6] Faculty of Educational Sciences and Technology, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia, 0009-0002-8889-9083
* Corresponding author: Mohamad Ikram Zakaria (mohamad.ikram@utm.my)

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Abstract

Digital pedagogies have emerged as a transformative force in mathematics education, offering dynamic, technology-driven approaches to teaching and learning. These pedagogical innovations support flexible, interactive, and student-centered learning environments, prompting a surge in scholarly interest. This study presents a bibliometric analysis aimed at identifying trends, prolific contributors, and core themes in the field of digital pedagogies in mathematics education from 2009 to 2025. A total of 119 publications were retrieved from the Scopus database, and tools such as biblioMagika® were employed for metric computation, OpenRefine for data harmonization, and VOSviewer for network visualization. The findings reveal a significant increase in research output post-2020, largely driven by the rapid digital transition caused by the COVID-19 pandemic. Countries such as Germany, Indonesia, and the United States were key contributors, while institutions like Johannes Kepler University, Universitas Syiah Kuala, and the University of Johannesburg demonstrated strong scholarly presence. The thematic analysis uncovered several major clusters, including technology-enhanced learning, blended and flipped classrooms, gamification, and emergency remote teaching. Frequently used keywords such as "digital pedagogy," "mathematics education," and "flipped classroom" reflect the field's evolving focus. The analysis recorded an h-index of 24 and a citation-per-publication rate of 20.08, underscoring robust academic engagement. This bibliometric overview offers meaningful insights for researchers, educators, and policymakers, and highlights the growing relevance of digital pedagogical strategies in reshaping mathematics education globally.

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Introduction

The integration of digital technologies into mathematics education has rapidly intensified in response to evolving educational demands shaped by the Fourth Industrial Revolution. As societies become increasingly dependent on data, connectivity, and automation, educational systems are compelled to adapt by incorporating digital pedagogies that foster mathematical reasoning, problem-solving, and digital literacy. The COVID-19 pandemic further underscored the urgency of these changes, highlighting the need for resilient and flexible learning models capable of supporting remote instruction (Alabdulaziz, 2021; Engelbrecht et al., 2020). In this context, digital pedagogies have become a vital mechanism in ensuring the continuity and quality of mathematics education across diverse learning environments (Albano et al., 2021).

Digital pedagogies encompass a broad spectrum of instructional methods and technological applications aimed at enhancing mathematics teaching and learning. These include flipped learning, blended learning, game-based learning, adaptive systems, and virtual learning environments, which are designed to personalize instruction and increase learner autonomy (Cevikbas & Kaiser, 2023; Barana & Marchisio, 2020). The use of tools such as GeoGebra, digital games, mobile apps, and e-learning platforms enables interactive, engaging, and context-responsive learning experiences (Fredriksen & Hadjerrouit, 2020; Ramli et al., 2022). Empirical evidence indicates that these approaches can improve students' understanding of abstract concepts and foster higher levels of motivation and participation (Bereczki et al., 2024; Dilling & Vogler, 2023).

The effectiveness of digital pedagogies in mathematics education is particularly evident in their ability to accommodate differentiated instruction and support diverse learners. These pedagogical innovations provide multimodal representations of mathematical content, allowing students to interact with visual, symbolic, and dynamic elements simultaneously (Bergvall & Dyrvold, 2021; Shvarts & van Helden, 2023). They also promote student-centered learning by facilitating self-paced exploration, peer collaboration, and formative assessment through technology-enhanced environments (Bosch & Laubscher, 2022; Muir et al., 2022). In underserved or geographically isolated regions, digital tools have proven instrumental in mitigating disparities in access to high-quality mathematics instruction (Mailizar et al., 2020).

Despite the proliferation of digital pedagogical strategies in mathematics education, the literature remains dispersed and fragmented across contexts, methodologies, and conceptual frameworks. Although numerous studies have explored specific tools or interventions, there is a lack of cohesive understanding regarding the evolution, trends, and key contributors within this body of knowledge. Bibliometric analysis offers a comprehensive and systematic approach to address this gap by uncovering patterns of publication, collaboration networks, citation dynamics, and thematic developments in the field (Bray & Tangney, 2017; Cevikbas & Kaiser, 2022). This method provides an evidence-based foundation for advancing theory, guiding research directions, and informing policy and practice.

This study seeks to map the landscape of digital pedagogies in mathematics education through a bibliometric review. By analyzing publications indexed in major scientific databases, the study aims to identify influential

authors, institutions, journals, and research themes that define the field. The insights generated from this analysis will help illuminate how digital pedagogies have shaped mathematics education over time and across regions. Ultimately, this review aspires to inform future pedagogical innovations and foster a strategic dialogue among educators, researchers, and policymakers working toward the advancement of mathematics education in the digital era.

Literature Review

The landscape of digital pedagogies in mathematics education has expanded significantly in recent years, driven by technological innovation, pedagogical reform, and unprecedented shifts in educational delivery. Studies have documented how diverse digital environments—ranging from learning management systems to adaptive platforms—transform the way mathematical concepts are taught and learned (Niño & Gómez, 2022; Bosch & Laubscher, 2022). These pedagogical advancements go beyond tool adoption by redefining instructional roles and enhancing learner agency, with emphasis placed on self-directed exploration and real-time formative feedback (Ramli et al., 2022; Dilling & Vogler, 2023). The rise of digital pedagogies is further evident in tertiary settings, where pre-service mathematics teachers increasingly engage with online and hybrid learning environments to build content mastery and pedagogical flexibility (Weinhandl et al., 2024).

A growing body of research supports the role of digital pedagogies in promoting mathematical thinking, particularly through learner-centered approaches such as flipped classrooms, blended learning, and game-based learning. These models are credited for fostering deeper engagement, cognitive activation, and collaboration among learners (Bruna et al., 2025; Jasmin & Ongcoy, 2024). Tools such as GeoGebra and EdPuzzle, when integrated into instructional design, have shown to facilitate spatial reasoning, procedural fluency, and conceptual understanding in diverse classroom contexts (Jiménez et al., 2021; Nasrullah et al., 2025). Furthermore, platforms offering adaptive features—like automated feedback and differentiated content paths—contribute to inclusive mathematics instruction by catering to varying learner abilities and learning paces (Attard & Holmes, 2022; Ramlee et al., 2019).

Digital pedagogies have also proven valuable in cultivating higher-order thinking skills and metacognitive awareness, particularly in learning environments that emphasize inquiry-based learning, problem-solving, and project-based approaches. Several studies highlight how multimodal resources and interactive simulations prompt learners to analyze, synthesize, and evaluate mathematical problems more critically (Bereczki et al., 2024; Barana & Marchisio, 2020). The use of digital storytelling embedded formative assessments, and gamified systems further reinforce retention and motivation while advancing learning outcomes (Calder, 2018; Dai et al., 2023). Notably, cognitive benefits from digital pedagogical strategies have been observed in both primary and postsecondary mathematics education settings (Setyo et al., 2023; Elsayed et al., 2025).

The recent global shift to emergency remote teaching prompted by the COVID-19 pandemic has accelerated the mainstreaming of digital pedagogies and revealed systemic gaps in digital readiness. Scholars reported mixed experiences, noting positive developments in teacher adaptability and student resilience, but also highlighted

digital equity challenges, instructional design constraints, and varied student perceptions (Moldavan et al., 2022; Chirinda et al., 2022). In response, researchers have proposed hybrid models that merge traditional practices with technological enhancements to sustain meaningful mathematical engagement (Callaghan et al., 2023; González & González, 2024). Additionally, teacher professional development and institutional support structures have been identified as critical factors for successful implementation of digital pedagogies in mathematics classrooms (Fredriksen, 2021; Kreis et al., 2024).

Despite the proliferation of empirical studies and theoretical frameworks, the literature on digital pedagogies in mathematics remains fragmented, with inconsistencies in terminology, scope, and methodological focus. While individual studies contribute valuable localized insights, a comprehensive synthesis of the field's evolution and research trends is needed. Existing literature reviews have primarily focused on specific tools or pedagogical models, leaving a gap in mapping the broader scholarly discourse across time and regions (Bray & Tangney, 2017; Cevikbas & Kaiser, 2023). Therefore, a bibliometric review is warranted to provide a systematic and macro-level understanding of the intellectual structure, collaboration patterns, and thematic developments within digital pedagogies in mathematics education.

Previous Studies on Bibliometric Analysis

Bibliometric analysis has become an increasingly utilized method for tracing the development of educational research, particularly in the domain of digital pedagogies in mathematics education. This quantitative approach enables scholars to map the growth of literature, identify influential contributors, and uncover thematic shifts across time. Through the systematic assessment of publication data, citation networks, and co-occurrence patterns, bibliometric studies offer valuable insights into how academic discourse evolves within specialized fields. While previous research has explored digital learning environments, these studies vary widely in scope, data coverage, and bibliometric parameters, revealing both achievements and gaps that warrant further inquiry.

A study by Santoveña-Casal and López (2023) focused on digital pedagogies in higher education using 498 documents indexed in Web of Science from 2003 to 2023. Their analysis highlighted annual publication trends, productive authors, contributing countries, leading institutions, and keyword co-occurrence. While their work provides a strong foundation, its exclusive focus on higher education limits its relevance for broader educational contexts such as primary or secondary mathematics classrooms. Additionally, the restricted data source may exclude significant contributions from other scholarly databases or non-English sources.

Another relevant bibliometric study by Düşünen and Ata (2023) investigated trends related to educational digital games in mathematics education. Drawing on 143 documents indexed in Scopus from 2010 to 2023, the study analyzed author keywords, prolific authors, publication sources, and international collaboration. This study's strength lies in its focus on gamification, a significant subdomain within digital pedagogy. However, its narrow thematic scope on digital games does not capture the broader spectrum of digital pedagogical approaches such as adaptive systems, flipped learning, or hybrid instructional models, thereby leaving gaps in understanding the full digital pedagogical landscape. In contrast, the study by Naser et al. (2023) offered a wider lens by reviewing

information and communication technology (ICT) applications in mathematics learning. An extensive dataset of 1,274 documents from Scopus covering 1999 to 2023 was analyzed to determine yearly publication growth, authorship patterns, country contributions, and keyword analysis. Although this study provides robust longitudinal data, the focus on general ICT rather than digital pedagogy limits its ability to capture the instructional designs, pedagogical theories, and evolving classroom practices central to the digital pedagogies' framework.

The temporal scope, research objectives, and bibliometric variables assessed in these studies differ considerably, impacting their ability to present a unified overview of digital pedagogy in mathematics. Furthermore, none of these works specifically address the post-pandemic transformation of digital pedagogical strategies in mathematics education, nor do they incorporate a comprehensive comparative lens across multiple educational levels. To address these limitations, the present study extends the analysis to digital pedagogies in mathematics education across broader contexts, educational levels, and geographic regions.

This study adopts a comprehensive bibliometric approach to map the scholarly landscape of digital pedagogies in mathematics education from 2010 to 2024. By analyzing publication trends, author productivity, country collaboration, and thematic patterns using Scopus-indexed literature, the study contributes a much-needed synthesis of this dynamic and multidisciplinary field. The goal is to build on existing bibliometric work by offering a contemporary, inclusive, and mathematics-specific review that can guide future research, inform educational policy, and support pedagogical innovation.

Research Questions

This study conducts a comprehensive bibliometric investigation into the domain of digital pedagogies within mathematics education by addressing the following six guiding research questions:

RQ 1: What is the current state of research pertaining to digital pedagogies in mathematics education?

RQ 2: What are the notable trends that have emerged in recent scholarly publications on digital pedagogical practices within mathematics education?

RQ 3: Which academic journals and publication sources have played central roles in disseminating influential research on digital pedagogies in mathematics education?

RQ 4: What are the pivotal scholarly works that have significantly shaped the discourse and trajectory of digital pedagogy research in the field of mathematics education?

RQ 5: Who are the prominent contributors, including individual authors, academic institutions, and nations, leading scholarly efforts in advancing digital pedagogies within the context of mathematics education?

RQ 6: What are the principal thematic areas that form the foundation for the development and progression of digital pedagogical approaches in mathematics education?

This inquiry seeks to provide a structured and comprehensive understanding of the evolution and scope of digital pedagogy research within mathematics education. By applying bibliometric and network analysis methods, the study systematically explores patterns of scholarly output, thematic concentrations, and collaborative dynamics in the field. The resulting insights contribute meaningfully to the advancement of research-informed pedagogical

practices aligned with contemporary technological developments. Ultimately, this analysis aims to illuminate both the historical context and present state of digital pedagogies in mathematics education, thereby offering a strategic foundation for future academic exploration and innovation in teaching and learning.

Methodology

The present study is grounded in bibliometric analysis using data obtained from the Scopus database as of August 4, 2025. Scopus was selected due to its broad disciplinary coverage and extensive indexing of peer-reviewed literature. The dataset extracted for this study included a variety of bibliometric variables, such as types of documents and publication sources, languages of publication, disciplinary subject areas, annual publication trends, average number of authors per article, institutional affiliations, geographical distribution of publications, and recurring author keywords. While Scopus offers a robust foundation for bibliometric research, it is important to recognize that reliance on a single database may limit the diversity and comprehensiveness of insights. Previous bibliometric studies in the domain of digital pedagogies in mathematics education have similarly drawn from a single data source, often Scopus, which can constrain the scope of the analysis. This study acknowledges this methodological limitation and recommends the integration of additional databases, including Web of Science and Google Scholar, in future research efforts. Such an approach would enable a more inclusive and representative mapping of scholarly developments across different indexing platforms and academic communities.

Search Strategy

The review process in this study was guided by a modified version of the PRISMA framework, also known as the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Moher et al., 2009). The search string ("Digital Pedagogy" OR "Digital Pedagogies" OR "Digital Teaching" OR "Technology-Enhanced Learning" OR "E-Learning" OR "Blended Learning" OR "Online Pedagogy") AND ("Math*" AND ("Educat*" OR "Learn*" OR "Teach*" OR "Pedagog*")) was entered into the Scopus search engine. Following the initial search, subject area filters were applied to refine the results. The screening criteria were defined based on the scope of the study, including search fields, publication years, source types, and document types, which helped exclude documents that were not aligned with the study's objectives. This process initially yielded 1005 documents. Abstracts of each entry were then reviewed systematically to determine topical relevance and eliminate those that did not meet the inclusion criteria. Upon completion of the screening procedure, a total of 119 documents were identified as relevant for the final dataset used in this bibliometric analysis of digital pedagogies in mathematics education (see Figure 1).

Data Cleaning and Harmonization

Ensuring accuracy and consistency in bibliometric analysis requires rigorous data cleaning and standardization procedures. In this study, two dedicated tools were employed to facilitate these processes: OpenRefine and biblioMagika® (Ahmi, 2023). These platforms are specifically designed to address inconsistencies in bibliographic data, particularly in author names, institutional affiliations, and keyword usage.

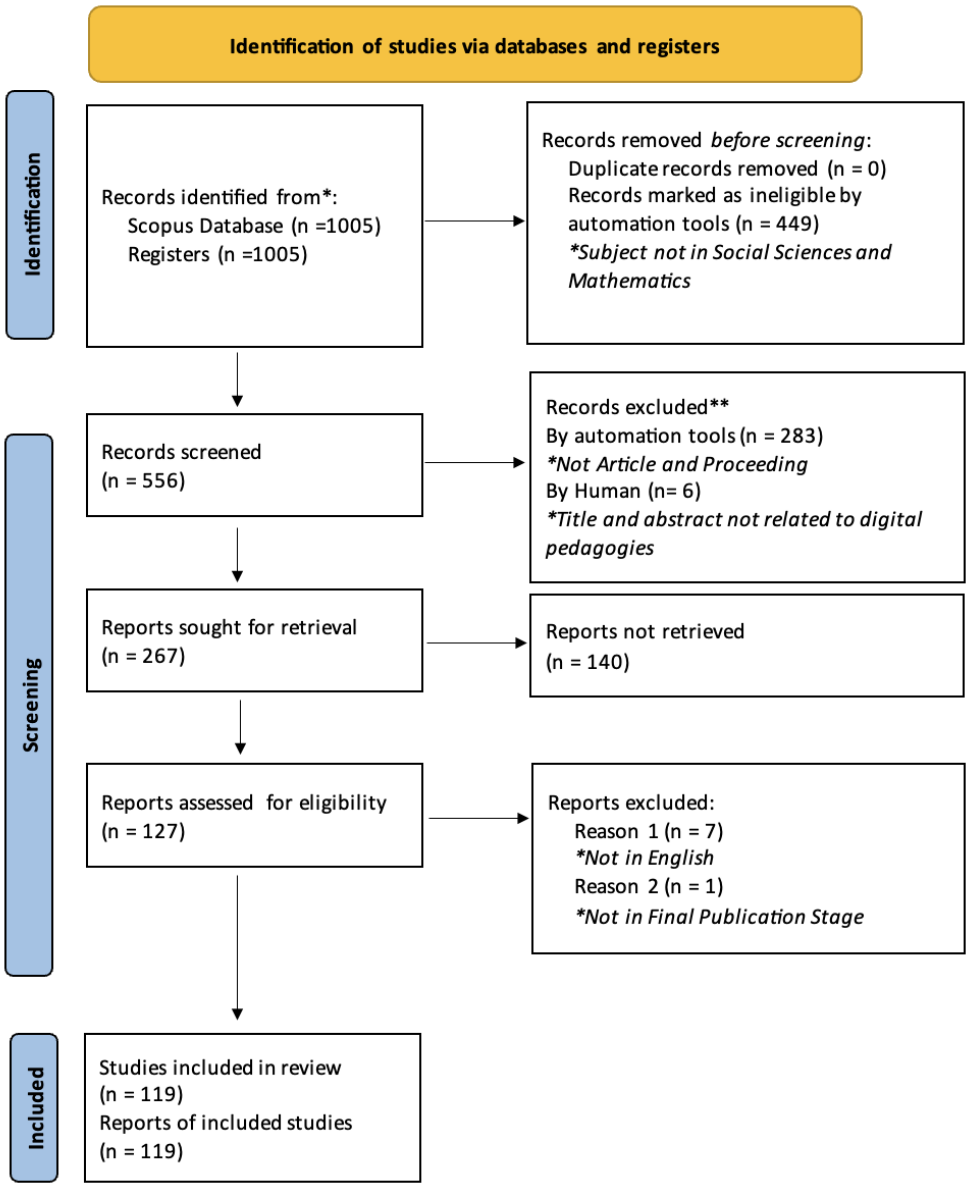

Figure 1. Flow Diagram of The Search Strategy

The cleaning process began with the extraction of data in comma-separated values (CSV) format, followed by the selection of relevant fields for refinement. Columns such as author names, keywords, and institutional affiliations were harmonized through a series of clustering and transformation operations within OpenRefine and biblioMagika®. Advanced bibliometric metrics were then generated using biblioMagika®. These included indicators such as Total Publications, Number of Contributing Authors, Number of Cited Publications, Total Citations, Citations per Publication, Citations per Cited Publication, Citations per Author, Authors per Publication, Citations per Year, and additional indices such as the h-index, g-index, m-index, and citation sum within the h-core. These calculations were carried out across multiple bibliographic categories including publication year, source titles, authorship, institutional affiliation, and geographical location. In addition, the software supported the identification and manual resolution of missing or incomplete data entries, thereby enhancing the overall quality and reliability of the dataset. The resulting dataset served as a robust and consistent foundation for subsequent analyses of digital pedagogies in mathematics education.

Data Analysis

The analytical strategy adopted in this study was explicitly aligned with the research questions, aiming to provide a detailed mapping of the research landscape in digital pedagogies within mathematics education. The analysis encompassed the classification of document types, source types, languages, subject areas, and citation indicators. Descriptive bibliometric techniques were used to present trends across variables such as publication frequency by year, contributions of leading authors, dominant institutions, publishing countries, and high-impact journals.

To assess research influence, core bibliometric indices were calculated, including the total number of publications, number of cited items, total citations, average citations per publication, average citations per cited work, and impact metrics such as the h-index, g-index, and m-index. To explore conceptual structures and research themes, the study employed several advanced bibliometric visualization techniques. These included co-occurrence network analysis, thematic mapping, and factorial analysis of author keywords. Such techniques enabled the identification of thematic clusters, examination of inter-topic relationships, and detection of evolving research areas within the domain. These findings contributed to a clearer understanding of the intellectual and conceptual landscape surrounding digital pedagogies in mathematics education.

Tools

A diverse suite of software tools was utilized to support the execution of this bibliometric review. Microsoft Excel served as the initial platform for organizing and preparing the raw data. OpenRefine was employed for detailed data harmonization, particularly for cleaning author keywords. BiblioMagika® facilitated comprehensive bibliometric profiling by managing the standardization of authorship, institutional data, and country affiliations.

For the visualization of bibliometric networks and thematic clusters, VOSviewer was applied, offering insight into keyword co-occurrence and collaboration patterns. Additionally, Mendeley functioned as the primary reference management system throughout the study. The integration of these tools ensured a systematic and methodologically sound approach to analyzing the scholarly discourse on digital pedagogies in mathematics education.

Results

The following section provides a comprehensive analysis of the research landscape concerning digital pedagogies in mathematics education. This analytical presentation is designed to directly address the research questions outlined earlier, offering a nuanced and in-depth understanding of the field. Through this structured exploration, the authors aim to deliver a critical and informative synthesis of current developments in digital pedagogical practices within mathematics education. The insights generated are intended to support academic discourse and offer meaningful contributions for researchers, educators, and policymakers engaged in advancing technology-enhanced teaching and learning.

Current State of Digital Pedagogies in Mathematics Education Research

To respond to the first research question regarding the current landscape of digital pedagogies in mathematics education, this study analyzed the distribution of publications across various bibliographic dimensions. These include document type, source category, language, and subject area. The dataset also underwent citation-based assessment to evaluate the impact and scholarly visibility of research outputs. A total of 119 documents, spanning from 2009 to 2025, were identified as relevant to the field (see Table 1). These comprised journal articles, conference proceedings, book chapters, and review papers. Conference papers frequently represent early-stage findings and are often expanded into more rigorous journal contributions. Collectively, these publications demonstrate a diversified knowledge base and a sustained academic interest in digital pedagogies applied within mathematics education.

Table 1. Citation Metric

Main Information	Data
Publication Years	2009 - 2025
Total Publications	119
Citable Year	17
Number of Contributing Authors	362
Number of Cited Papers	108
Total Citations	2,389
Citation per Paper	20.08
Citation per Cited Paper	22.12
Citation per Year	149.31
Citation per Author	6.60
Author per Paper	3.04
Citation sum within h-Core	2,210
h-index	24
g-index	46
m-index	1.412

The analysis revealed that the 119 documents were authored by 362 unique contributors, indicating a robust culture of academic collaboration. Among these works, 108 were cited, reflecting widespread engagement from the scholarly community. A total of 2,389 citations were recorded across the dataset, yielding an average of 20.08 citations per publication. When examining only the cited documents, the average citation rate increased to 22.12, signifying notable academic influence. The coverage of 17 citable years further illustrates the temporal breadth of the dataset, with an average of 149.31 citations per year. The average number of authors per publication was 3.04, suggesting frequent co-authorship practices. Additionally, the average number of citations per author stood at 6.60, highlighting the research contributions made by individual scholars within this domain.

Key bibliometric indices were used to quantify scholarly performance. The h-index was calculated at 24,

indicating that 24 publications had received at least 24 citations each. The g-index was found to be 46, while the m-index stood at 1.412, reflecting the sustained scholarly impact over time. The total citation sum within the h-core was 2,210, emphasizing a concentrated body of influential literature. Collectively, these indicators confirm that research on digital pedagogies in mathematics education constitutes a growing and impactful academic field. The findings demonstrate the presence of consistent citation performance, dynamic co-authorship networks, and a maturing research trajectory, positioning this area as a significant contributor to the broader discourse on technology-integrated teaching and learning.

Notable Patterns of Digital Pedagogies in Mathematics Education

To explore the second research question, this study investigated the chronological development of research on digital pedagogies in mathematics education. The earliest relevant publication appeared in 2009, signaling the initial scholarly attention to this emerging area. Since then, the number of publications and citations has shown a gradual upward trend with notable increases in specific years. The year 2022 recorded the highest number of publications, totaling 26 documents, whereas 2020, despite producing only 14 papers, generated the largest number of citations at 935. This citation spike suggests that highly influential studies were published during this period, likely in response to global shifts in educational practices during the COVID-19 pandemic. The distribution of scholarly output over time indicates not only a growing body of literature but also heightened academic relevance driven by evolving pedagogical needs.

The period between 2020 and 2023 demonstrated the most substantial concentration of academic activity. Within these four years, 85 publications were produced, generating 1,810 citations, which together account for more than 75 percent of the total citations recorded in the dataset. The year 2023 alone yielded 20 documents and 195 citations, reflecting sustained research interest. Although there was a slight decrease in both publication output and citation frequency in 2024 and 2025, the continuity of research contributions highlights the ongoing importance of this topic. The number of contributing authors also expanded significantly, rising from 8 in 2009 to 69 in 2023. This growth points to increased collaboration and diversification within the research community, involving contributors from interdisciplinary domains such as educational technology, mathematics instruction, and digital learning design.

From a bibliometric standpoint, indicators such as the h-index, g-index, and m-index provide further evidence of the field's maturing influence. The h-index reached its highest point of 10 in 2021, indicating that ten publications from that year or earlier were cited at least ten times. The g-index peaked at 17 in 2022, while the m-index recorded its strongest value of 2.667 in 2023, reflecting consistent scholarly impact in recent years. Although annual fluctuations were observed, such variations are typical of emerging fields and often shaped by publication cycles and citation practices. Overall, the results demonstrate that digital pedagogies in mathematics education have evolved into a dynamic and impactful research area. The growing publication volume, increasing author participation, and strengthening citation metrics collectively affirm the field's expanding contribution to educational research and innovation.

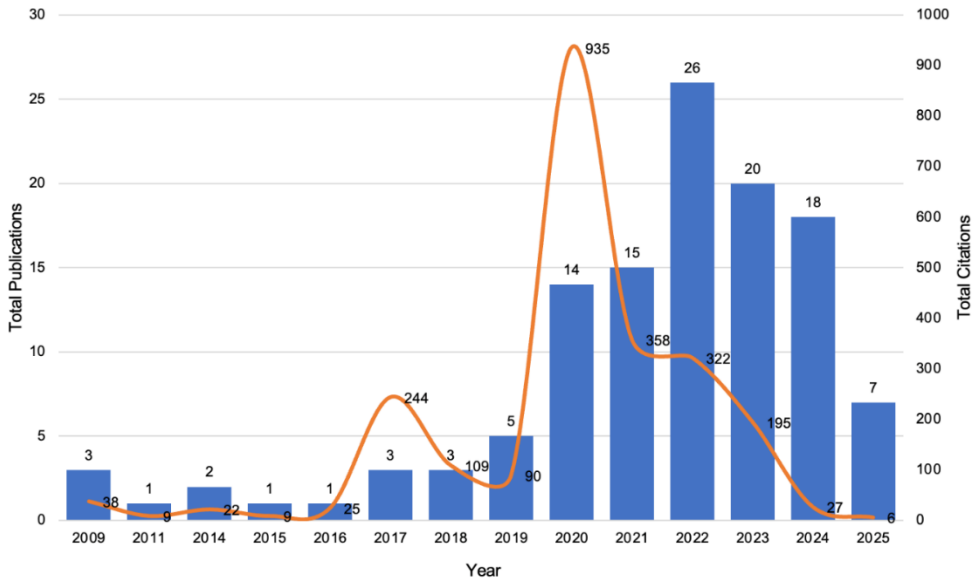

Figure 2. Total Publications and Citations by Year (as data is only available up to 5 August 2025)

Table 2. Yearly Output of Publications

Year	TP	NCA	NCP	TC	C/P	C/CP	*h*	*g*	*m*
2009	3	8	3	38	12.67	12.67	2	3	0.118
2011	1	1	1	9	9.00	9.00	1	1	0.067
2014	2	6	2	22	11.00	11.00	2	2	0.167
2015	1	4	1	9	9.00	9.00	1	1	0.091
2016	1	1	1	25	25.00	25.00	1	1	0.100
2017	3	4	3	244	81.33	81.33	3	3	0.333
2018	3	6	3	109	36.33	36.33	3	3	0.375
2019	5	16	5	90	18.00	18.00	5	5	0.714
2020	14	34	14	935	66.79	66.79	9	14	1.500
2021	15	42	15	358	23.87	23.87	10	15	2.000
2022	26	82	25	322	12.38	12.88	9	17	2.250
2023	20	69	20	195	9.75	9.75	8	13	2.667
2024	18	60	13	27	1.50	2.08	3	3	1.500
2025	7	29	2	6	0.86	3.00	2	2	2.000
Total	**119**	**362**	**108**	**2389**	**20.08**	**22.12**	**24**	**46**	**1.412**

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.

* Publication data for the year 2025 is only up until 12 February 2025.

Academic journals of Digital Pedagogies in Mathematics Education

Table 3 identifies the most active journals publishing research on digital pedagogies in mathematics education,

focusing on those with at least three publications. *Education Sciences* ranks as the most prolific source, contributing nine publications and accumulating 220 citations. This results in a citation-per-publication (C/P) value of 24.44. The journal holds an h-index of 6, a g-index of 9, and an m-index of 0.750, indicating a sustained and influential presence in the field. Close behind is *ZDM – Mathematics Education*, which has published seven papers garnering 273 citations, leading to the highest C/P value of 39.00 among all listed sources. With an h-index of 6 and a g-index of 7, ZDM demonstrates strong academic recognition and efficient citation performance. These two journals collectively serve as central platforms for scholarly discussions on the integration of digital pedagogies in mathematics education.

Table 3. Journal with Two (2) or More Publications

Source Title	**TP**	**NCA**	**NCP**	**TC**	**C/P**	**C/CP**	***h***	***g***	***m***
Education Sciences	9	27	9	220	24.44	24.44	6	9	0.750
ZDM - Mathematics Education	7	24	7	273	39.00	39.00	6	7	1.000
International Journal of Emerging Technologies in Learning	7	15	6	86	12.29	14.33	4	7	0.235
Eurasia Journal of Mathematics, Science and Technology Education	5	16	3	436	87.20	145.3 3	3	5	0.333
International Journal of Mathematical Education in Science and Technology	4	9	4	72	18.00	18.00	3	4	0.333
Cogent Education	4	15	3	75	18.75	25.00	2	4	0.400
International Journal of Information and Education Technology	4	13	2	5	1.25	2.50	1	2	0.167
Computers and Education	4	14	4	234	58.50	58.50	4	4	0.444
Frontiers in Education	4	25	3	35	8.75	11.67	2	4	0.500
Teaching Mathematics and its Applications	3	9	3	47	15.67	15.67	3	3	0.250
International Journal of Science and Mathematics Education	3	6	3	92	30.67	30.67	3	3	0.600

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

Other journals also contribute significantly in terms of either volume or citation quality. The *International Journal of Emerging Technologies in Learning* and the *Eurasia Journal of Mathematics, Science and Technology Education* have published seven and five articles respectively. Notably, the Eurasia journal stands out with 436 citations, yielding an exceptional C/P of 87.20. Despite a relatively modest h-index of 3 and a g-index of 5, this indicates that a small number of its publications have had considerable academic impact. Similarly, *Computers and Education* recorded four publications but achieved a substantial 234 citations, resulting in a C/P value of 58.50. Its h-index and g-index of 4 and m-index of 0.444 confirm its position as a high-impact outlet, despite limited output. These examples demonstrate that while publication quantity is one indicator of influence, citation-based metrics offer a deeper understanding of research visibility and quality.

In addition, journals such as *Teaching Mathematics and Its Applications*, *International Journal of Mathematical Education in Science and Technology*, *International Journal of Science and Mathematics Education*, and *Cogent Education* contribute moderately to the field. For example, *Teaching Mathematics and Its Applications* produced three articles with 47 citations and a C/P of 15.67, while the *International Journal of Science and Mathematics Education* had a strong C/P of 30.67 from just three publications. These findings reflect the multidimensional and interdisciplinary nature of the field, where research intersects pedagogy, technology, and subject-specific instruction. Overall, the performance of these journals, assessed through h-index, g-index, m-index, and citation-per-publication metrics, suggests that while some journals lead in output volume, others distinguish themselves through concentrated citation impact. This diversity highlights the importance of evaluating both productivity and scholarly influence in understanding the evolving landscape of digital pedagogies in mathematics education.

Pivotal Scholarly Works of Digital Pedagogies in Mathematics Education

Table 4 outlines the ten most frequently cited publications that have made substantial contributions to the discourse on digital pedagogies in mathematics education. At the top of the list is the work by Mailizar et al. (2020), which examined Indonesian secondary school mathematics teachers' perceptions of barriers to e-learning during the COVID-19 pandemic. This study recorded 392 total citations, with an average of 65.33 citations per year, highlighting its significance in shaping pandemic-related digital learning strategies. Close behind is the study by Mulenga and Marbán (2020), which interrogated whether the pandemic served as a gateway to broader digital adoption in mathematics education. This publication received 188 citations and a yearly average of 31.33, indicating substantial academic engagement. Also prominent is the systematic review by Bray and Tangney (2017), which analyzed trends in technology use in mathematics education, yielding 175 citations and a citation rate of 19.44 per year, underscoring the value of evidence synthesis in the field.

Engelbrecht et al. (2020) contributed a pivotal article investigating how internet-based learning has transformed mathematics classrooms. This study garnered 132 citations and achieved an annual citation rate of 22.00, reflecting its importance in conceptualizing digitally driven pedagogical change. Cevikbas and Kaiser (2020) offered insights into the flipped classroom model as a reform-oriented instructional method in mathematics, receiving 75 citations and 12.50 citations per year, further supporting the relevance of reversed instructional design in digital contexts. Similarly, Anderson et al. (2018) examined teacher adaptation to blended learning environments, resulting in 72 citations and an annual average of 9.00. These findings highlight the diverse pedagogical approaches contributing to the evolution of technology-enhanced mathematics instruction.

Additional influential studies include Christopoulos and Sprangers (2021), who explored the reception of educational technology by teachers and students during the pandemic, collecting 71 citations and a yearly average of 14.20. Alabdulaziz (2021) investigated the use of digital technology in mathematics education under pandemic conditions and achieved 68 citations with a yearly average of 13.60. Attard and Holmes (2022) examined perceptions of blended learning in secondary mathematics classrooms, with 65 citations and a high annual citation rate of 16.25. Lastly, Chirinda et al. (2021) assessed mathematics teaching practices during lockdown among historically disadvantaged populations, receiving 55 citations and averaging 11.00 citations per year. Collectively,

these top-cited articles represent a concentrated body of work that not only responded rapidly to global educational disruptions but also advanced key themes such as technological integration, blended learning, flipped instruction, and equity. Their influence underscores the critical role of digital pedagogies in reconfiguring mathematics education during times of crisis and beyond.

Table 4. Top Ten (10) Publication Articles

No.	Author(s)	Title	TC	C/Y
1	Mailizar et al. (2020)	Secondary school mathematics teachers' views on e-learning implementation barriers during the COVID-19 pandemic: The case of Indonesia	392	65.33
2	Mulenga & Marbán (2020)	Is covid-19 the gateway for digital learning in mathematics education?	188	31.33
3	Bray & Tangney (2017)	Technology usage in mathematics education research – A systematic review of recent trends	175	19.44
4	Engelbrecht et al. (2020)	Transformation of the mathematics classroom with the internet	132	22.00
5	Cevikbas & Kaiser (2020)	Flipped classroom as a reform-oriented approach to teaching mathematics	75	12.50
6	Anderson et al. (2018)	Achieving elusive teacher change through challenging myths about learning: A blended approach	72	9.00
7	Christopoulos & Sprangers (2021)	Integration of educational technology during the Covid-19 pandemic: An analysis of teacher and student receptions	71	14.20
8	Alabdulaziz (2021)	COVID-19 and the use of digital technology in mathematics education	68	13.60
9	Attard & Holmes (2022)	An exploration of teacher and student perceptions of blended learning in four secondary mathematics classrooms	65	16.25
10	Chirinda et al. (2021)	Teaching mathematics during the COVID-19 lockdown in a context of historical disadvantage	55	11.00

Prominent Authors, Academic Institutions, and Countries of Digital Pedagogies in Mathematics Education Research

Table 5 highlights the most prolific contributors in the field of digital pedagogies in mathematics education, focusing on authors with a minimum of two publications. Zsolt Lavicza from Johannes Kepler University in Austria leads with five publications and 69 citations, reflecting a citation-per-publication (C/P) value of 13.80. Lavicza's academic consistency is further evidenced by an h-index of 4, a g-index of 5, and an m-index of 0.667. Equally impactful are Mustafa Cevikbas and Gabriele Kaiser from the University of Hamburg, each with three

publications and a combined total of 157 citations. Their shared C/P of 52.33 and h- and g-indices of 3 underscore their strong and focused influence in the domain.

Table 5. Top-contributing Authors that Published More than Two (2) Documents

Full Name	Current Affiliation	Country	TP	NCP	TC	C/P	C/CP	h	g	m
Lavicza, Zsolt	Johannes Kepler University	Austria	5	5	69	13.80	13.80	4	5	0.667
Cevikbas, Mustafa	University of Hamburg	Germany	3	3	157	52.33	52.33	3	3	0.500
Kaiser, Gabriele	University of Hamburg	Germany	3	3	157	52.33	52.33	3	3	0.500
Vandervieren, Ellen	University of Antwerp	Belgium	3	3	55	18.33	18.33	3	3	0.750
Weinhandl, Robert	Johannes Kepler University	Austria	3	2	18	6.00	9.00	1	3	0.167
Juandi, Dadang	Universitas Pendidikan Indonesia	Indonesia	2	1	5	2.50	5.00	1	2	0.250
Ndlovu, Mdutshekelwa	University of Johannesburg	South Africa	2	2	59	29.50	29.50	2	2	0.400
Mailizar, M.	Universitas Syiah Kuala	Indonesia	2	2	394	197.00	197.00	2	2	0.333
Drijvers, Paul	Utrecht University	Netherlands	2	2	28	14.00	14.00	2	2	0.167
Spangenberg, Erica	University of Johannesburg	South Africa	2	2	59	29.50	29.50	2	2	0.400
Schallert, Stefanie	Johannes Kepler University	Austria	2	2	47	23.50	23.50	2	2	0.500
Engelbrecht, Johann	University of Pretoria	South Africa	2	2	139	69.50	69.50	2	2	0.333
Fredriksen, Helge	University of Agder	Norway	2	2	40	20.00	20.00	2	2	0.333
Chirinda, Brantina	University of Johannesburg	South Africa	2	2	59	29.50	29.50	2	2	0.400
Kreis, Yves	University of Luxembourg	Luxembourg	2	2	5	2.50	2.50	1	2	0.333
Naidoo, Jayaluxmi	University of KwaZulu-Natal	South Africa	2	2	51	25.50	25.50	2	2	0.333
Haas, Ben	Johannes Kepler University	Austria	2	2	5	2.50	2.50	1	2	0.333

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

Ellen Vandervieren from the University of Antwerp follows with three papers and 55 citations, supported by a C/P of 18.33 and h-, g-, and m-indices of 3, 3, and 0.750, respectively. Other contributors such as Robert Weinhadl and Stefanie Schallert from Austria demonstrate moderate impact, while South African scholars Mdutshekelwa Ndlovu and Erica Spangenberg register a joint output of two publications and 59 citations each, yielding a C/P of 29.50. Remarkably, Mailizar M. from Universitas Syiah Kuala in Indonesia stands out with only two publications but an extraordinary 394 citations, resulting in the highest C/P of 197.00 in the dataset. Additional contributors, including Paul Drijvers, Johann Engelbrecht, and Helge Fredriksen, add to the international diversity and underscore the global engagement shaping this field.

Table 6. Top-contributing Institutions with a Minimum of Five (5) Publications

Institution Name	**Country**	**TP**	**NCP**	**TC**	**C/P**	**C/CP**	***h***	***g***	***m***
Johannes Kepler University	Austria	14	12	156	11.14	13.00	7	12	1.167
IPN – Leibniz Institute for Science and Mathematics Education	Germany	8	8	208	26.00	26.00	8	8	2.000
Universitas Syiah Kuala	Indonesia	7	7	794	113.43	113.43	2	7	0.333
University of Johannesburg	South Africa	6	6	177	29.50	29.50	4	6	0.800
Utrecht University	Netherlands	6	6	80	13.33	13.33	6	6	0.500
UCL Institute of Education	United Kingdom	5	5	15	3.00	3.00	3	3	1.500
Western Sydney University	Australia	5	5	169	33.80	33.80	5	5	1.000
South Kazakhstan State Pedagogical University	Kazakhstan	5	5	25	5.00	5.00	5	5	1.250
Linnæus University	Sweden	5	5	5	1.00	1.00	1	2	0.500
Sapienza University of Rome	Italy	5	5	105	21.00	21.00	5	5	1.000
TU Dortmund University	Germany	5	0	0	0.00	0.00	0	0	0.000
M. Auezov South-Kazakhstan University	Kazakhstan	5	5	15	3.00	3.00	3	3	1.500
University of Tasmania	Australia	5	5	150	30.00	30.00	5	5	1.250
University of Turku	Finland	5	5	155	31.00	31.00	5	5	0.714

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

Table 6 further illustrates the institutional landscape of digital pedagogy research in mathematics education by identifying organizations with at least five publications. Johannes Kepler University leads with 14 publications and 156 citations, achieving a C/P of 11.14 and supported by an h-index of 7, g-index of 12, and m-index of 1.167. The IPN – Leibniz Institute for Science and Mathematics Education in Germany follows with eight publications and 208 citations, holding the highest h-index of 8 and m-index of 2.000, signifying both volume and high impact. Universitas Syiah Kuala in Indonesia makes a significant contribution with seven publications and 794 citations, yielding a striking C/P of 113.43, although with a modest h-index of 2. The University of Johannesburg in South

Africa is another key player, with six publications generating 177 citations and producing a C/P of 29.50, supported by h-, g-, and m-indices of 4, 6, and 0.800. Other active institutions include Utrecht University (Netherlands), UCL Institute of Education (UK), and Western Sydney University (Australia). While Utrecht and UCL show moderate outputs, Western Sydney achieves stronger visibility with a C/P of 33.80 and 169 total citations. Additional institutions such as South Kazakhstan State Pedagogical University, Sapienza University of Rome, the University of Tasmania, and the University of Turku also demonstrate emerging influence, with several reporting citation averages above 30. These findings reflect a robust and distributed academic ecosystem that spans continents and institutional types.

Table 7 and Figure 3 examine the global distribution of scholarly contributions, highlighting countries with nine or more publications in the field. The United States leads with 42 publications and 582 citations, averaging 13.86 citations per article, alongside an h-index of 13, g-index of 24, and m-index of 0.765. Germany ranks second with 37 publications and 673 citations, achieving the highest h-index of 18 and m-index of 3.000, which points to exceptional productivity and influence. Indonesia follows with 27 publications and the highest citation average of 30.78, supported by a g-index of 27 and an m-index of 0.833, reflecting strong regional leadership. South Africa ranks next with 23 publications and 478 citations, resulting in a C/P of 20.78, while Italy, with 19 publications and 226 citations, maintains steady impact with an h-index of 10 and m-index of 1.667.

Table 7. Top-contributing Countries that Produced Ten (10) or More Publications

Country	**TP**	**NCP**	**TC**	**C/P**	**C/CP**	***h***	***g***	***m***
United States	42	42	582	13.86	13.86	13	24	0.765
Germany	37	29	673	18.19	23.21	18	25	3.000
Indonesia	27	16	831	30.78	51.94	5	27	0.833
South Africa	23	23	478	20.78	20.78	10	21	0.909
Italy	19	16	226	11.89	14.13	10	15	1.667
Austria	18	14	191	10.61	13.64	8	13	1.333
Australia	14	14	371	26.50	26.50	11	14	1.222
Finland	13	13	250	19.23	19.23	9	13	0.818
Spain	13	13	686	52.77	52.77	7	13	1.167
United Kingdom	12	12	151	12.58	12.58	5	12	0.333
Kazakhstan	12	10	40	3.33	4.00	5	6	1.250
Malaysia	12	12	81	6.75	6.75	3	9	0.429
Turkey	10	10	34	3.40	3.40	4	5	0.333
Sweden	9	9	15	1.67	1.67	2	3	0.400
Ireland	9	9	407	45.22	45.22	6	9	0.353

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

Austria and Australia contribute 18 and 14 papers, respectively, with Australia reporting a high C/P of 26.50 and an h-index of 11. Spain and Finland both report 13 publications, but Spain distinguishes itself with the second-

highest citation average of 52.77 per paper. Meanwhile, the United Kingdom, Kazakhstan, and Malaysia each contributed 12 publications, albeit with varying citation levels. Ireland, despite having only nine publications, achieved a remarkable citation average of 45.22, positioning it among the most efficient contributors in terms of citation impact. Collectively, these metrics highlight the dynamic and globally distributed nature of research in digital pedagogies, underscoring both regional strengths and the collaborative momentum driving the field forward.

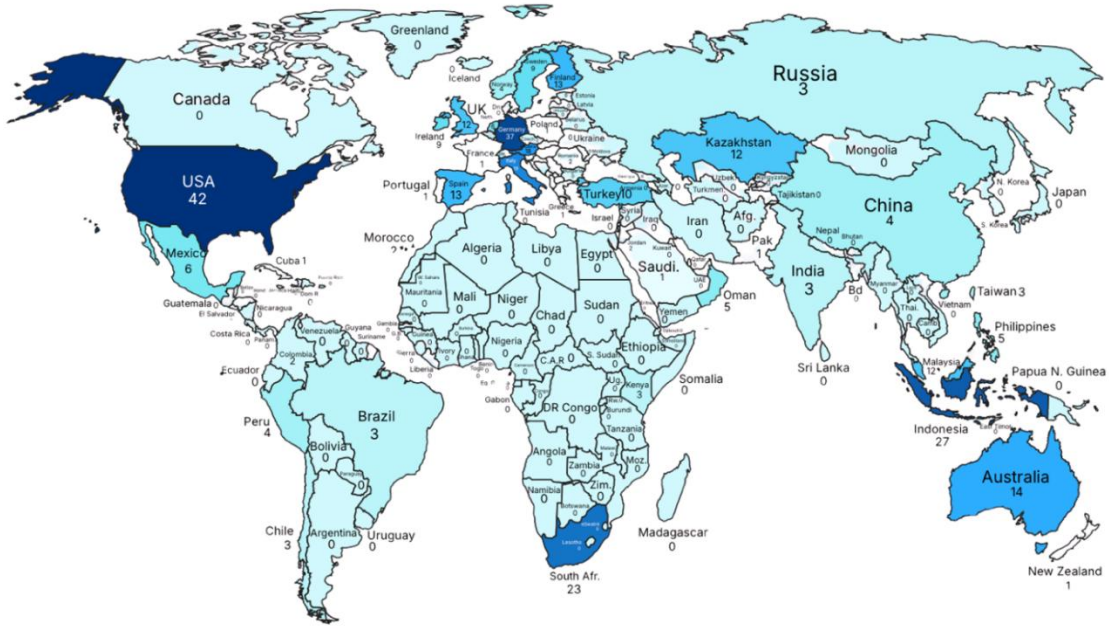

Figure 3. Visualization of Global Distribution of Digital Pedagogies in Mathematics Education Research

Principal Thematic Areas of Digital Pedagogies in Mathematics Education Research

Figure 4 presents a co-occurrence network that maps dominant research themes and their interconnections within the field of digital pedagogies in mathematics education. This visualization is based on author keywords that appeared ten times or more across the dataset, allowing for the identification of frequently discussed concepts and their relational patterns. At the center of the network lies “mathematics education,” which functions as the primary node, reflecting its pivotal position in the scholarly discourse. Closely associated terms such as “e-learning,” “technology enhanced learning,” and “teaching” form direct links to the central theme, suggesting that pedagogical strategies and technological integration are foundational components of research in this area.

The proximity of these nodes reveals an embedded relationship between instructional innovation and digital delivery mechanisms. The network also reveals several thematic clusters that indicate the presence of subfields and specialized research directions. One prominent cluster revolves around “e-learning,” “computer-aided instruction,” “adaptive learning,” “game-based learning,” and “learning systems.” This grouping reflects the technological underpinnings of contemporary mathematics instruction and points to a growing emphasis on personalized, automated, and engaging learning experiences.

The inclusion of gamification and adaptive technologies suggests an evolving pedagogical orientation that

prioritizes interactivity and student-centered approaches. Another notable cluster is anchored by "technology-enhanced learning" and connects to terms like "digital technologies," "engineering education," and "secondary school," highlighting ongoing efforts to embed digital tools into formal educational structures, particularly in secondary and STEM-related contexts. A separate but interconnected thematic area includes keywords such as "flipped classroom," "blended learning," "higher education," and "mathematics teaching," indicating a shift toward hybrid learning models that combine digital resources with in-person instruction. This is complemented by a cluster containing terms like "COVID-19," "emergency remote teaching," "elementary education," and "digital learning," which underscores the field's responsiveness to global educational disruptions.

The presence of these terms suggests sustained interest in understanding how the pandemic accelerated the implementation of digital pedagogies across various educational levels. Overall, the co-occurrence network offers a structural lens for interpreting thematic relationships and highlights how digital innovations—including blended learning, gamification, adaptive tools, and emergency strategies—are reshaping mathematics education. This visual mapping provides a valuable framework for future research, offering direction for scholars seeking to explore emerging pedagogical paradigms within a digitally mediated educational landscape.

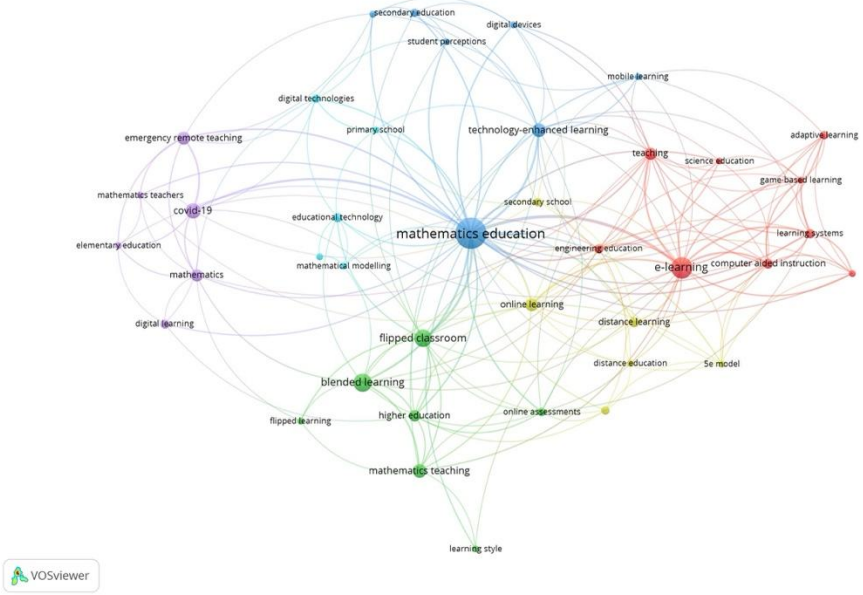

Figure 4. Author Keyword Network with a Minimum of Three Occurrences

Discussion and Conclusion

The bibliometric analysis indicated a significant growth in research output on digital pedagogies in mathematics education, particularly after 2019. While initial contributions from 2007 to 2018 remained limited, the sudden global shift to online learning during the COVID-19 pandemic catalyzed a surge in scholarly activity. This abrupt transition spurred urgent innovation among educators and researchers, especially in countries with advanced digital infrastructure (Mulenga & Marbán, 2020; Engelbrecht et al., 2020). The increase in publication volume during this period reflects the academic community's responsiveness in identifying and addressing challenges linked to remote teaching, learner engagement, and instructional adaptation.

The most highly cited studies in this field emerged during the pandemic years, addressing pressing pedagogical challenges. Notably, Mailizar et al. (2020) captured attention by investigating Indonesian secondary school teachers' perspectives on digital barriers in mathematics instruction. Similarly, Bray and Tangney (2017) conducted a systematic review of technology integration trends, highlighting critical developments. Other impactful works examined blended learning (Anderson et al., 2018), emergency remote teaching (Chirinda et al., 2021), and student-centered approaches such as flipped classrooms (Cevikbas & Kaiser, 2020). These works received high citation rates due to their timeliness, contextual relevance, and practical implications for reshaping mathematics education during and beyond the pandemic.

Author-level and institutional contributions underscored the global and interdisciplinary nature of this research domain. Prominent figures such as Zsolt Lavicza (Johannes Kepler University) and Gabriele Kaiser (University of Hamburg) consistently contributed high-impact publications, especially on themes like game-based learning, flipped classrooms, and inquiry-driven instruction (Schallert et al., 2022). Institutions such as the Leibniz Institute (Germany) and Universitas Syiah Kuala (Indonesia) stood out for either productivity or citation impact. Remarkably, despite fewer outputs, Universitas Syiah Kuala recorded one of the highest citation-per-publication ratios, signaling significant global influence (Mailizar et al., 2020). These contributions emphasize the strategic role of both established and emerging institutions in advancing pedagogical innovation.

Thematic mapping of the literature revealed interconnected research clusters anchored in key concepts such as mathematics education, technology-enhanced learning, and flexible instructional models. Keywords like "e-learning," "gamification," "adaptive learning," and "flipped classroom" reflected an increasing shift toward personalized, engaging, and resilient pedagogies (Fredriksen, 2021; Bereczki et al., 2024). Notably, the COVID-19 pandemic served as a powerful catalyst for exploring these models at various educational levels, with a sustained emphasis on scalability and accessibility (Alabdulaziz, 2021). In sum, this review not only confirms the dynamic evolution of digital pedagogies in mathematics education but also highlights its ongoing potential to redefine teaching and learning practices in a digitally transformed era.

This bibliometric review underscores the accelerating growth and global significance of digital pedagogies in mathematics education, particularly in response to the pedagogical shifts prompted by the COVID-19 pandemic. The surge in scholarly output, coupled with increasing citation impact, reflects active contributions from authors, institutions, and countries across diverse regions such as Europe, Southeast Asia, and Africa. Central themes including blended learning, flipped classrooms, gamification, and technology-enhanced instruction indicate a clear movement toward more interactive, flexible, and student-centered approaches. While digital tools have been essential in mitigating educational disruptions, they are also redefining the long-term future of mathematics instruction. To build on the insights from this analysis, future research should incorporate additional databases to broaden the bibliographic scope, utilize altimetric indicators to assess societal relevance, and include content analyses to deepen understanding of theoretical and methodological orientations. There is also a pressing need to explore how digital pedagogies address equity, accessibility, and cultural diversity, particularly in underrepresented regions. Longitudinal and predictive studies can further illuminate emerging trends, while empirical investigations linking digital instructional models to student outcomes such as performance, motivation,

and engagement will provide practical validation. Advancing these areas will strengthen the development of innovative, inclusive, and sustainable pedagogical strategies for the digital era of mathematics education, promoting critical thinking, collaborative learning, and real-world problem-solving skills for students globally.

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