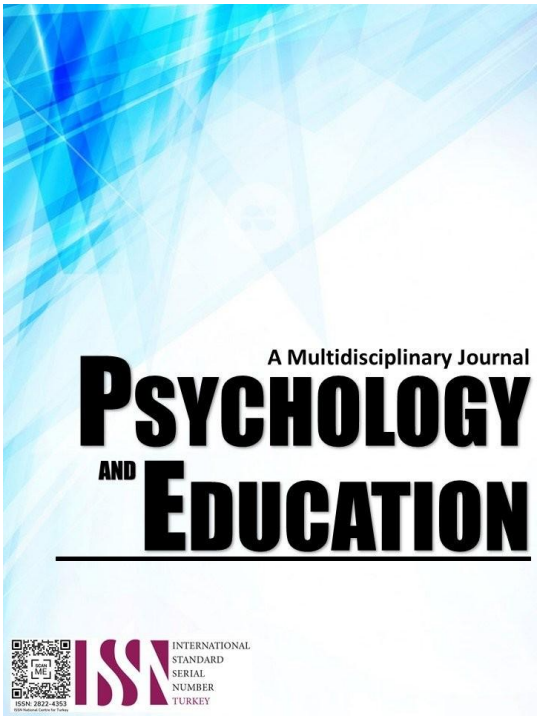
FROM EMERGENCY TO TRANSFORMATION IN MATHEMATICS EDUCATION: A BIBLIOMETRIC ANALYSIS OF THE COVID-19 ERA AND BEYOND



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Research Article

From Emergency to Transformation in Mathematics Education: A Bibliometric Analysis of the COVID-19 Era and Beyond

Hanifah E. Daluma,* Aniceto B. Naval
For affiliations and correspondence, see the last page.

Abstract

When classrooms closed and chalkboards gave way to webcams, mathematics education rapidly shifted to digital and remote modalities, prompting a corresponding surge in research. As the crisis unfolded, scholarly priorities moved from emergency responses to more sustainable and innovation-focused approaches. This bibliometric study analyses 237 peer-reviewed publications from 2020 to 2025, retrieved from Lens.org through a targeted search. Records lacking author-supplied keywords were supplemented with an AI-assisted extraction of salient terms that researchers then verified and standardized. VOSviewer 1.6.20, a specialized software for visualizing bibliometric networks, produced keyword co-occurrence, citation, co-authorship, and bibliographic-coupling maps that reveal thematic clusters and patterns of influence. Results indicate a clear thematic evolution. Early studies concentrated on online access and emergency remote instruction, whereas later work emphasized blended-learning design, teacher agency in hybrid contexts, equity and access, assessment reform, and professional development. Citation analysis highlights a core set of highly influential documents that guided subsequent research. At the same time, co-authorship mapping identifies collaborative networks led mainly by scholars in the United States, the Netherlands, Germany, and the United Kingdom. Bibliographic coupling uncovers cohesive clusters centered on resilient, technology-enhanced pedagogies and equity-oriented frameworks. Overall, the findings trace mathematics-education research as it progressed from short-term solutions to durable instructional innovations.

Keywords*: mathematics education, COVID-19, blended learning bibliometric analysis, educational technology, VOSviewer*

Introduction

The COVID-19 pandemic has fundamentally reshaped education systems worldwide, prompting a rapid shift from traditional classroom instruction to emergency remote teaching. In mathematics education, this disruption sparked an unprecedented wave of adaptations—from digitized lesson delivery and restructured assessments to revised pedagogical strategies and emergent technological integration. The transition from emergency responses to more sustainable, research-informed approaches shaped the trajectory of mathematics education research in the post-pandemic years. This transition from emergency response to educational innovation has catalyzed a growing body of scholarship seeking to interrogate, document, and improve mathematics teaching and learning during and after the crisis.

As the global education community confronts the long-term implications of the pandemic, it becomes increasingly important to examine how research in mathematics education has responded, adapted, and evolved. Bibliometric analysis offers a systematic approach to map thematic evolution, identify influential contributors, and uncover intellectual structures within mathematics education research. Through techniques such as keyword co-occurrence, citation analysis, and bibliographic coupling, this method captures both the breadth and interconnectedness of scholarly activity, making it well-suited for understanding research shifts brought about by the COVID-19 pandemic.

The COVID-19 pandemic precipitated an unprecedented shift in education, compelling institutions worldwide to transition rapidly to emergency remote teaching (ERT). In the realm of mathematics education, this abrupt change posed unique challenges due to the subject's inherent reliance on visual representations and interactive problem-solving. Ní Fhloinn and Fitzmaurice (2021) conducted a comprehensive survey involving 257 mathematics lecturers across 29 countries, revealing that over 90% had minimal prior experience with online teaching. The majority found the transition stressful and time-consuming, citing significant challenges related to technology, student engagement, and the abstract nature of mathematics itself. While prior studies have explored emergency teaching and initial blended learning adaptations, there is limited analysis of how research themes in mathematics education have evolved thematically and structurally since the onset of the pandemic. This study aims to map the evolution of mathematics education research from 2020 to 2025 using bibliometric analysis, with particular focus on emerging themes, influential scholars, and patterns of interconnectedness based on shared references.

Further studies have echoed these early findings, highlighting the significant challenges educators faced in adapting to online platforms without adequate preparation or institutional support. Driskell et al. (2023) documented the experiences of mathematics teacher educators during the pandemic, identifying recurring issues such as instructional difficulties, rapid technological tool adoption, and the emotional burden of transitioning to digital instruction. As the immediate crisis waned, attention turned toward developing more sustainable and intentional approaches to technology integration. Baidoo (2024) proposed a theoretical framework for implementing blended teaching methodologies in South African high schools, combining face-to-face and digital pedagogies to address longstanding

inequities and prepare students for a more connected future. Building on this momentum, Lima, Silva, and Khan (2025) examined the broader adaptation of blended learning models in post-pandemic educational systems, noting their potential to deliver personalized and flexible instruction. However, they also emphasized persistent challenges such as limited infrastructure and the continued need for teacher training and professional development to ensure effective implementation.

This study investigates mathematics education research produced between 2020 and 2025, through bibliometric analysis to capture the field's evolving priorities and patterns. Bibliometric analysis is defined as the use of combined frameworks, tools, and methods to study scholarly citations and produce metrics that reveal an academic field's intellectual structure and evaluate the impact of journals, publications, and researchers (Akhavan et al., 2016; Mahi, 2021; Ponce & Lozano, 2010). Hu and Wang (2023) observed that bibliometric trends in economics during the COVID-19 and related epidemic periods showed an initial surge of crisis-focused publications, which gradually transitioned to more targeted, long-term research priorities. VOSviewer was selected for its capacity to generate bibliometric maps that visualize co-authorship networks, keyword co-occurrence patterns, and bibliographic coupling. This allowed the study to trace how themes and collaborations evolved. In addition, AI-assisted techniques such as automated keyword enrichment and metadata cleaning were used to enhance data quality and ensure consistency across sources.

Research Questions

This study aimed to examine the development of mathematics education during and after the COVID-19 pandemic by addressing the following research questions:

1. What are the most dominant research themes in mathematics education from 2020 to 2025, based on the co-occurrence of author keywords?
2. Who were the most influential authors and collaborative networks driving mathematics education research during the COVID-19 era and its aftermath?
3. Which countries contributed most significantly to the global research output in mathematics education between 2020 and 2025?
4. Which documents, journals, and authors demonstrated the highest citation impact in mathematics education research throughout the COVID-19 and post-pandemic years?
5. In what ways are mathematics education studies from 2020 to 2025 thematically interconnected, as revealed through bibliographic coupling analysis?
6. How have key themes and priorities in mathematics education research evolved over time, based on author keywords, abstracts, and title terms from 2020 to 2025?

Methodology

Research Design

This study employed a bibliometric research design to examine how mathematics education research evolved from 2020 to 2025 in response to the COVID-19 pandemic. The bibliometric approach was used to identify prevailing themes, influential contributors, and collaborative patterns within the field. Rather than analyzing the content of individual studies, this method focused on broader publication trends, such as frequently occurring keywords, highly cited works, and the network structures connecting authors, journals, and documents. For instance, Jantan and Idrus (2022) conducted a bibliometric review of The Mathematics Journal from 2000 to 2020, demonstrating how keyword co-occurrence and citation mapping can reveal evolving thematic clusters, a method we adapted for post-pandemic analysis. Similar methodological choices have been employed beyond mathematics education; for example, Rodriguez and Naval (2025) mapped 14 years of chatbot research in education using Lens.org data and VOSviewer, underscoring the value of co-occurrence, citation, and coupling analyses for charting emerging technology trends.

Procedure

Bibliometric data were extracted from Lens.org, a publicly accessible and multidisciplinary research database. The search was performed under the Scholarly Works category using the following query: ("mathematics education" OR "math education") AND (("digital learning" OR "online learning" OR "remote learning" OR e-learning OR technology) AND (COVID-19 OR pandemic OR coronavirus)), which initially yielded 480 results.

The initial search yielded 480 results. Articles were filtered based on specific criteria, including a publication year range from 2020 to 2025. The scope was further narrowed by selecting studies within relevant fields such as pedagogy, educational technology, pandemic-related education, mathematics, mathematics education, online learning, and COVID-19. Subject areas included developmental and educational psychology, computational mathematics, computer science applications, education, applied mathematics, and other closely related disciplines. A title- and keyword-level screening was conducted to exclude records not directly related to mathematics or mathematics education, reducing the dataset to 329 entries. Further refinement involved removing duplicates, standardizing metadata, and excluding records with incomplete information—such as missing abstracts or author fields—resulting in a final dataset of 237 qualified studies. The finalized dataset was exported in CSV format and analyzed using VOSviewer. The analysis involved co-authorship mapping to examine research collaborations, keyword co-occurrence to reveal dominant themes, citation analysis to identify

influential publications, and bibliographic coupling to uncover thematic linkages among studies. This systematic approach supported the reliability, transparency, and reproducibility of the results.

Data Analysis

All bibliometric analyses were conducted using Microsoft Excel and VOSviewer (version 1.6.20), a software package widely used for constructing and visualizing bibliometric networks. VOSviewer was selected for its capacity to generate cluster-based maps of keyword co-occurrence, author collaboration, citation networks, and bibliographic coupling, fully aligning with the study's analytical goals. To ensure consistency and completeness across records, several data-cleaning procedures were implemented. Author names were standardized, including the correction of character-encoding issues such as non-ASCII characters (e.g., "Barzel"). Duplicate entries were removed by matching Lens IDs and titles. AI-assisted techniques were applied in a limited, targeted manner to enrich metadata for studies that lacked author-supplied keywords: ChatGPT generated preliminary keyword suggestions from titles and abstracts, which researchers then reviewed for contextual accuracy. After enrichment, a VOSviewer thesaurus file was applied to merge synonymous and variant terms (e.g., "remote learning," "online learning") under unified headings, ensuring consistency in the co-occurrence analysis. The finalized dataset was exported in CSV format and analyzed in VOSviewer. Keyword co-occurrence analysis, using a minimum occurrence threshold of three, produced cluster and overlay visualizations to identify dominant research themes. Author-based co-authorship analysis, with thresholds of at least two publications and two link strengths, revealed influential researchers and collaborative networks. Country-level co-authorship mapping examined international contributions using a minimum of two publications per country. Citation analysis assessed the impact of documents, authors, and journals, while bibliographic coupling mapped thematic linkages based on shared references, thereby revealing underlying structural connections in the field.

Ethical Considerations

This study adhered to ethical research standards by utilizing publicly accessible data sourced from Lens.org, an open-access academic database. As the research did not involve human participants or any personally identifiable information, there were no associated risks to privacy or confidentiality. The analysis was limited to bibliometric metadata, including publication information, citation counts, and authorship networks, and did not alter, manipulate, or misrepresent the content of the original works. All AI-assisted keyword suggestions were handled with researcher oversight to ensure accuracy and responsible use.

Results and Discussion

Problem 1. What were the most dominant and evolving research themes in mathematics education from 2020 to 2025, as revealed by author keyword co-occurrence and temporal trends?

Table 1. *Top Co-occurring Keywords in Mathematics Education Research (2020–2025, N = 237)*

Rank	*Keyword (label after thesaurus merge)*	*Occurrences*	*Total link strength3*
1	mathematics education	83	141
2	teachers	30	68
3	learning	24	60
4	online learning	23	49
5	students	21	45
6	education	17	38
7	covid-19	28	31
8	study	10	26
9	digital	10	25
10	pandemic	12	25
11	digital technology	12	24
12	covid	9	23
13	research	6	15
14	resources	5	12
15	equity	8	11
16	professional development	9	11
17	mathematics learning	7	10
18	online teaching	6	10
19	STEM education	6	10
20	TPACK	6	10

As shown in Table 1, mathematics education emerged as the most frequently occurring and centrally connected keyword in the 2020–2025 dataset (83 occurrences; TLS = 141). Other high-frequency terms, such as teachers (n = 30) and students (n = 21) emphasize the human dimension of pandemic-era scholarship. Meanwhile, keywords like online learning (n = 23; TLS = 49) and digital technology (n = 12; TLS = 24) reflect the field's strong orientation toward technology-mediated instruction during the crisis period.

Pandemic-specific terms—including COVID-19, COVID, and pandemic—appeared a combined 49 times and were moderately linked with pedagogical terms. This suggests that many studies explicitly situated their inquiries within the pandemic context. Although less frequent, concepts related to equity, resources, professional development, and curricular frameworks such as STEM education and TPACK demonstrated meaningful linkages, pointing to a thematic transition from emergency response to broader concerns of access and instructional quality.

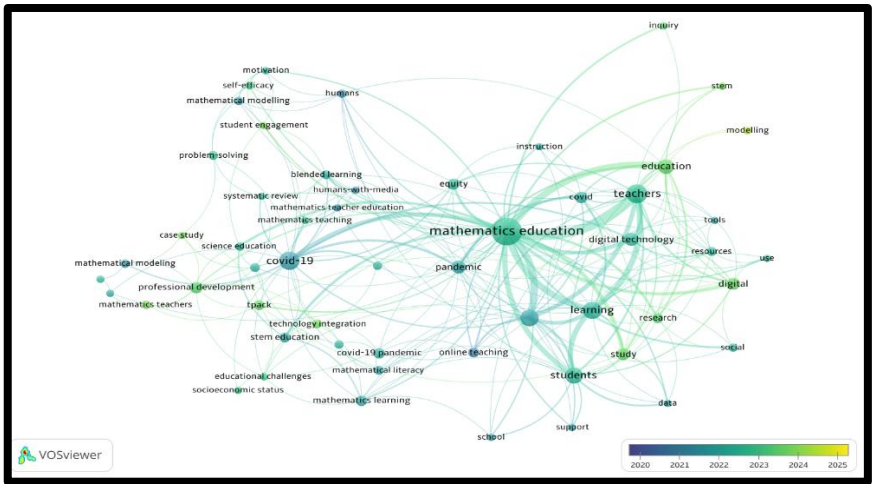

Figure 1. *Overlay co-occurrence map of author keywords/enriched terms in mathematics-education research with minimum = 3*

Thematic keyword analysis across the years revealed that mathematics education consistently remained the dominant term, anchoring the literature. However, keyword trends over time reflect a clear evolution in focus. For instance, teachers peaked in 2022, mirroring heightened interest in their adaptive roles during remote and hybrid learning phases. This was followed by rising attention to technology integration and blended learning, particularly in 2023 and 2024, indicating a shift toward more sustainable pedagogical models.

Newly emerging topics such as problem solving, STEM, modelling, and equity began gaining traction, especially from 2022 onward. These trends point to a growing interest in fostering deeper cognitive engagement, interdisciplinary learning, and more inclusive digital practices. Collectively, these findings confirm a thematic evolution in mathematics education research—from managing immediate disruptions to reimagining instruction with long-term innovation and equity in mind.

Problem 2. Who were the most influential authors and collaborative networks driving mathematics education research during the COVID-19 era and its aftermath?

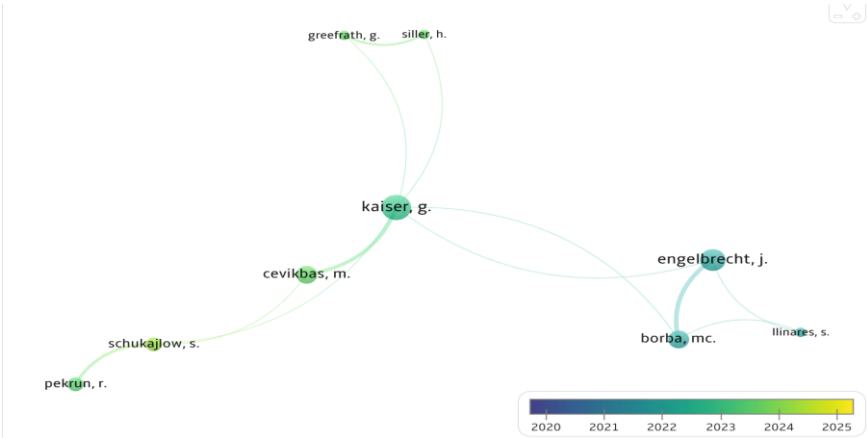

Figure 2. *Visualization of the Co-authorship Network of Connected Authors (n = 9) (min of 2 documents)*

The co-authorship analysis revealed a relatively sparse network, with only nine authors forming interconnected collaborative groups out of a total of 75 authors in the dataset. As shown in Table 2, Engelbrecht, J. emerged as the most central figure with five documents, 223 citations, and the highest total link strength (TLS = 4), indicating strong collaborative influence. Other productive authors included Li, M. (8 publications), Cevikbas, M., and Schukajlow, S., each associated with three or more co-authored works and moderate TLS

values.

Despite high publication and citation counts among individual authors, the overall network density remains low, suggesting that much of the research in this field is produced by isolated or loosely connected scholars. This is visualized in Figure 2, where only a small subset of authors forms tightly linked collaborative clusters. For example, a strong triad is observed between Engelbrecht, J., Borba, M.C., and Llinares, S., while another cluster centers around Kaiser, G. and collaborators.

The network further reveals that collaborations typically occur within small, discipline-specific teams rather than as part of large-scale, international consortia. This may reflect the emergent nature of mathematics education research during and immediately after the pandemic, where geographic and institutional constraints limited broader collaboration.

Problem 3. Which countries contributed most significantly to the global research output in mathematics education between 2020 and 2025?

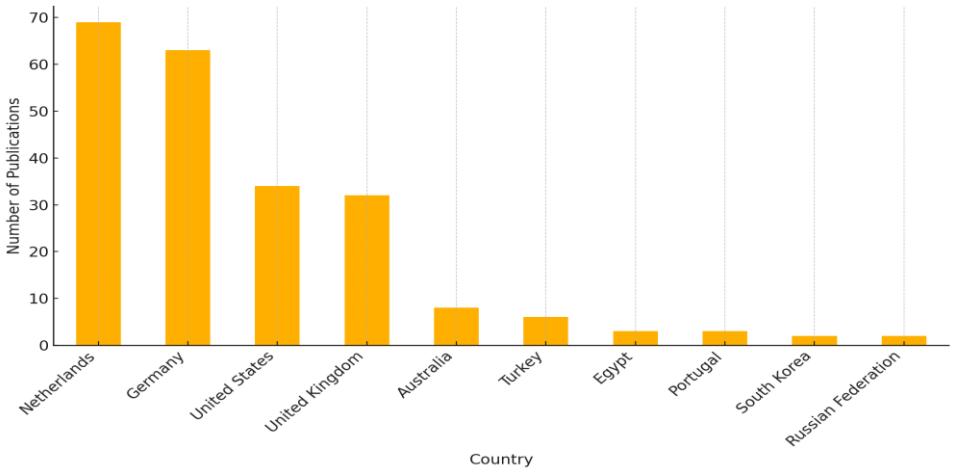

Figure 3. *Top 10 Publishing Countries in Mathematics Education Research (2020–2025)*

The analysis of publication origins based on journal Source Country revealed a geographically concentrated research landscape. The Netherlands emerged as the leading publishing country, contributing 69 articles (29.1%), followed closely by Germany with 63 publications (26.6%). The United States (n = 34; 14.3%) and the United Kingdom (n = 32; 13.5%) also showed strong representation. Beyond these four dominant countries, the number of publications dropped sharply, with Australia (n = 7), Turkey (n = 5), and South Africa (n = 4) rounding out the mid-tier contributors. Canada, Italy, and Spain each produced three publications during the same period.

Problem 4. Which documents, journals, and authors demonstrated the highest citation impact in mathematics education research throughout the COVID-19 and post-pandemic years?

Table 2. *Most Cited Documents in Mathematics-Education Research (2020–2025)*

Title	*Author/s*	*Citing Count*	*Source*
Transformation of the mathematics classroom with the internet.	Johann Engelbrecht; Salvador Llinares; Marcelo C. Borba	162	ZDM : the international journal on mathematics education
Future themes of mathematics education research: an international survey before and during the pandemic	Arthur Bakker; Jinfa Cai; Linda Zenger	128	Educational studies in mathematics
Teaching with digital technology.	Alison Clark-Wilson; Ornella Robutti; Mike Thomas	120	ZDM : the international journal on mathematics education
Pandemic: lessons for today and tomorrow?	Arthur Bakker; David Wagner	100	Educational studies in mathematics
The future of mathematics education since COVID-19: humans-with-media or humans-with-non-living-things	Marcelo de Carvalho Borba	95	Educational studies in mathematics
Did students learn less during the COVID-19 pandemic? Reading and mathematics competencies before and after the first pandemic wave	Johannes Schult; Nicole Mahler; Benjamin Fauth; Marlit A. Lindner	72	School Effectiveness and School Improvement
COVID-19 and the use of digital technology in mathematics education.	Mansour Saleh Alabdulaziz	65	Education and information technologies
Distance mathematics teaching in Flanders, Germany, and the Netherlands during COVID-19 lockdown	Paul Drijvers; Daniel Thurm; Ellen Vandervieren; Marcel Klinger; Filip Moons; Heleen van der Ree;	58	Educational studies in mathematics

	Amy Mol; BÃ¤rbel Barzel; Michiel Doorman		
Emotions and motivation in mathematics education: Where we are today and where we need to go.	S Schukajlow; K Rakoczy; R Pekrun	51	ZDM : the international journal on mathematics education
Mathematical Analysis of the Effects of Controls on Transmission Dynamics of SARS-CoV-2	Joshua Kiddy K. Asamoah; Christopher Saaha Bornaa; Seidu; Zhen Jin	45	Alexandria Engineering Journal

Table 3. *Top 10 Most Cited Authors in Mathematics-Education Research (2020–2025)*

Rank	*Author*	*Citing Works Count*
1	Arthur Bakker	228
2	Johann Engelbrecht	223
3	Marcelo C. Borba	186
4	Salvador Llinares	162
5	David Wagner	130
6	Jinfa Cai	128
7	Linda Zenger	128
8	Ornella Robutti	124
9	Mike Thomas	120
10	Alison Clark-Wilson	120

Table 4. *Top 10 Most Cited Journals in Mathematics-Education Research (2020–2025)*

Rank	*Journal*	*Total Citations*
1	ZDM The International Journal on Mathematics Education	836
2	Educational studies in mathematics	655
3	Education and information technologies	210
4	International journal of science and mathematics education	85
5	School Effectiveness and School Improvement	72
6	Alexandria Engineering Journal	45
7	Mathematics Education Research Journal	39
8	Asia Pacific Education Review	35
9	Pythagoras	29
10	Teaching Mathematics and its Applications: An International Journal of the IMA	29

As presented in Tables 2 to 4, the most cited documents in the dataset—many published during the early phase of the pandemic (2020–2021)—garnered over 200 citations, reflecting their high impact and relevance in addressing immediate educational disruptions such as emergency remote teaching, digital pedagogy, and teacher adaptation. The top-cited authors included Borba, M. C., Engelbrecht, J., and Bakker, A., each of whom contributed multiple influential works on digital transformation and blended learning in mathematics education.

These scholars were also prominent in the co-authorship network, underscoring their central role in shaping the discourse of the field. While Western academic institutions remained dominant, the diversity of national affiliations among top-cited authors points to a gradual decentralization of scholarly influence.

In terms of publication venues, ZDM – The International Journal on Mathematics Education led with 836 citations (after correcting for character encoding issues), followed by Educational Studies in Mathematics (655 citations) and Education and Information Technologies (210 citations). The prominence of ZDM and ESM highlights the importance of specialized mathematics education journals in supporting rigorous, peer-reviewed dialogue during global disruption. In contrast, the visibility of technology-focused journals reflects the growing integration of digital platforms in mathematics instruction during and beyond the pandemic.

Problem 5. How are mathematics education studies from 2020 to 2025 thematically interconnected, based on bibliographic coupling patterns?

The visualization shows that early-pandemic literature (2020–2021) is not siloed from post-pandemic work (2023 onward). Instead, recent studies are deeply grounded in earlier conceptual discussions, signaling an evolution from emergency pedagogies to more refined, theoretically embedded models of digital mathematics education. Figure 4 further illustrates these findings by clustering

documents into distinct but interconnected research.

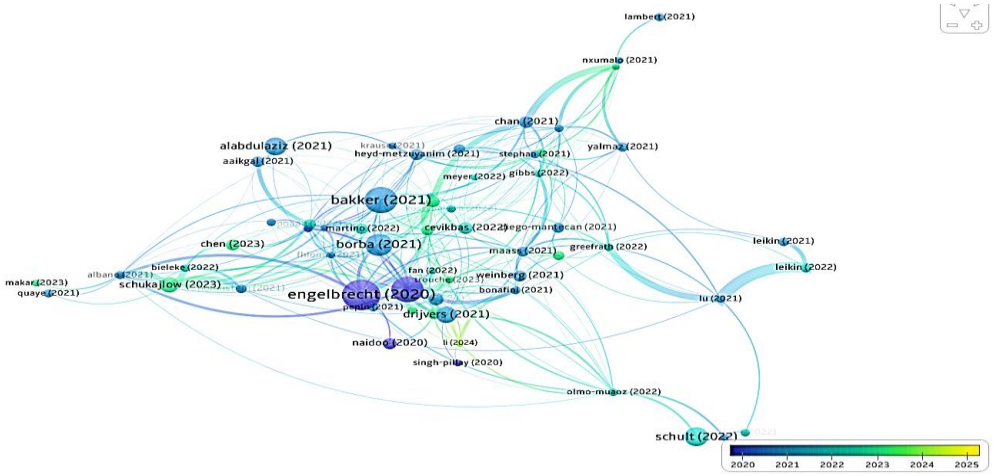

Figure 4. *Bibliographic Coupling Network of Documents in Mathematics Education Research (2020–2025) communities*

Problem 6. How have key themes and priorities in mathematics education research evolved over time, based on author keywords, abstracts, and title terms from 2020 to 2025?

The temporal analysis of keyword trends in mathematics education research reveals distinct phases of thematic emphasis across the six years. As shown in Figure 5, research priorities evolved alongside the shifting educational context from the height of the COVID-19 pandemic to the subsequent post-pandemic transition. The grouped keyword "Mathematics Education" maintained a consistently high frequency throughout all years, peaking in 2022. This trend confirms the enduring centrality of the discipline in scholarly discourse and its adaptability to pandemic-driven pedagogical challenges.

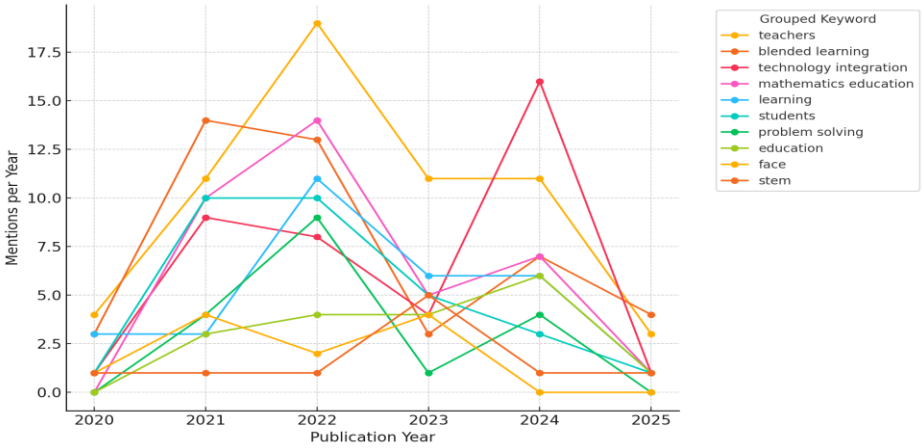

Figure 5. *Temporal Trends of Key Terms in Mathematics Education Research (2020–2025), Based on Author Keywords, Abstracts, and Titles*

The group "Teachers" experienced a notable surge in 2022, reflecting intense academic attention on teachers' roles in remote instruction, pedagogical adjustments, and professional development. However, this interest gradually declined in 2023–2025, possibly indicating a shift in focus from teacher-led adaptations to broader systemic innovations. "Technology Integration" and "Blended Learning" displayed parallel upward trajectories, particularly gaining strength in 2023 and 2024, suggesting a transition from reactive digital strategies to more sustainable and embedded technological practices. This progression underscores the field's movement from emergency digital adaptation to more intentional and theoretically grounded tech-enhanced instruction.

Terms such as "Problem Solving," "Assessment," and "Modelling" remained relatively steady with minor fluctuations, indicating their relevance as foundational constructs in mathematics education regardless of modality or delivery format. Meanwhile, "Equity" and "STEM" emerged with lower but stable visibility beginning in 2022, reflecting the growing recognition of inclusion, access, and interdisciplinary connections as long-term concerns beyond the pandemic.

The observed keyword shifts mirror established models of educational change: early peaks in "Mathematics Education," "Teachers," and COVID-specific terms align with the "survival" stage of emergency remote teaching (Hodges et al., 2020), when research focused on rapid teacher adaptation. Subsequent rises in "Technology Integration" and "Blended Learning" during 2023-2024 correspond to

Rogers's (2003) normalization phase of innovation diffusion, indicating a move from ad-hoc fixes to embedded digital practices. Core constructs such as "Problem Solving," "Assessment," and "Modelling" remained stable, reflecting Kilpatrick, Swafford, and Findell's (2001) enduring strands of mathematical proficiency. Finally, the post-2022 emergence of "Equity" and "STEM" echoes calls for socially just, interdisciplinary mathematics education (Gutiérrez, 2013; English, 2016), showing that researchers are now framing technology-enhanced instruction within broader equity and cross-disciplinary agendas.

The timeline mirrors known change models. Early focus on teaching adaptation (survival phase) gave way to blended and tech-integrated strategies (normalization). Later, research turned to social justice, interdisciplinary learning, and sustainable models of instruction.

Conclusions

This bibliometric analysis provides a comprehensive overview of how mathematics education research evolved in response to the COVID-19 pandemic and in its aftermath, spanning the years 2020 to 2025. The study revealed that "mathematics education," "online learning," "teachers," and "digital technology" were among the most dominant and interconnected themes, particularly during the early phase of the pandemic.

The co-authorship and citation analyses identified a small number of highly influential authors, including Borba, Engelbrecht, and Bakker, whose work on digital transformation and instructional innovation helped shape the field's direction. Citation mapping also revealed that studies published during the early pandemic, especially those addressing urgent instructional disruptions, were among the most cited. This highlights the value of timely, solution-oriented research during crises.

Country-level analysis underscored the prominence of Western contributors, although increased global collaboration was observed, signaling a gradual shift toward more diverse participation. Journals such as ZDM, Educational Studies in Mathematics, and Education and Information Technologies emerged as key platforms for high-impact research dissemination.

Bibliographic coupling analysis further revealed the emergence of cohesive thematic clusters, marking a shift from reactive, emergency-driven solutions to deeper pedagogical inquiry. Temporal trends based on keywords, titles, and abstracts demonstrated a clear evolution from emergency remote teaching toward sustainable blended learning models, enhanced teacher agency, and a growing concern for equity and inclusive practices in digital mathematics education. Taken together, these findings confirm that mathematics education research during the pandemic was not only reactive but also progressively adaptive. The field has moved toward long-term pedagogical innovation, digital transformation, and inclusive education. This trajectory reflects the field's resilience, responsiveness, and commitment to equitable educational transformation in the face of global disruption.

To sustain and build upon the momentum in mathematics education research, educational leaders, journal editors, and funding bodies should foster international collaboration and prioritize research that advances equity, inclusion, and innovation. Special attention should be given to supporting scholars from underrepresented regions such as Africa, Latin America, and Southeast Asia through targeted funding programs, research exchange initiatives, and special journal issues.

Future studies should also extend beyond short-term assessments of emergency teaching practices and instead explore the longitudinal effects of blended and hybrid learning models. Combining quantitative metrics (for example, performance data and engagement statistics) with qualitative insights (such as teacher interviews and student surveys) will help capture the full complexity of technology-mediated learning. Applying equity-focused frameworks, such as Universal Design for Learning or culturally responsive pedagogy, will be essential to ensure digital innovations benefit all learners, particularly those from marginalized groups.

Improving research infrastructure is equally critical. Journals and indexing databases should encourage the consistent use of author identifiers (such as ORCID) and promote detailed keyword tagging to minimize bibliographic inconsistencies. Support for open-access publishing, preprint sharing, and collaborative data repositories will enhance transparency and accelerate knowledge dissemination. Finally, researchers are encouraged to adopt emerging bibliometric and computational tools, including text mining, topic modeling, and social network analysis. These methods can help uncover novel trends such as AI-supported instruction, cross-disciplinary STEM integration, and teacher professional development in digital contexts. These steps will help shape a more robust, inclusive, and future-oriented body of mathematics education research.

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Affiliations and Corresponding Information

Hanifah E. Daluma
Pantar National High School
Department of Education – Philippines

Aniceto B. Naval, PhD
Northwestern Mindanao State College of Science and Technology – Philippines