Post-Pandemic Trends in Mathematics Education: A Bibliometric Study on the Flipped Classroom Approach (2022-2024)

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Abstract
Flipped classroom pedagogy has emerged as an innovative approach in mathematics education, promising to enhance student engagement, deepen conceptual understanding, and improve learning outcomes. This study aimed to map the research landscape of flipped classrooms in mathematics education from 2022 to 2024 through a bibliometric analysis of 253 publications retrieved from the ERIC database. The bibliometric analysis, using Biblioshiny, revealed a significant disparity in author productivity, with a small group of researchers contributing a disproportionate share of publications. Furthermore, the study identified key journals and analyzed the co-occurrence of keywords, revealing two major research clusters: core pedagogical themes and the integration of technology and contemporary challenges. The analysis highlighted the influence of high-impact journals, particularly those from the United Kingdom and the United States, on the field. These findings underscore the need to encourage collaboration among researchers, diversify funding sources, and promote equitable access to research publications to ensure a more inclusive and impactful research landscape in flipped classroom mathematics education.
Keywords: Bibliometric analysis; flipped classroom; mathematics education; technology integration; post COVID-19

Introduction

The COVID-19 pandemic has significantly impacted various sectors, including education. To curb the virus's spread, governments worldwide were compelled to shut down schools and educational institutions, leading to a sudden shift from face-to-face learning to online education. This transition was not merely a change in medium but also brought new challenges affecting learning effectiveness, particularly in subjects like mathematics that demand active interaction and deep exploration.

Numerous studies have highlighted the pandemic's effects on education. For instance, Bao reported challenges such as technological gaps and reduced student engagement during online learning (Bao, 2020). Similarly, Hodges et al. emphasized that emergency remote teaching often lacked the effectiveness of well-designed online education (Hodges et al., 2020). The limitations of traditional teaching methods, particularly in virtual settings, underscored the need for innovative approaches to foster student engagement and interactive learning.

During the pandemic, flipped classroom practices gained significant traction as a response to these challenges. Flipped classrooms invert the traditional learning model by enabling students to access basic instructional content independently through videos or other materials before class sessions (Zhang et al., 2024). This approach allows in-class time to be devoted to higher-order activities, such as problem-solving and collaborative learning. In mathematics education, the flipped classroom model holds great potential to enhance students' understanding of concepts, promote critical thinking, and facilitate collaborative skills.

Many studies have documented the effectiveness of flipped classrooms in improving learning outcomes and engagement of students. Flipped classrooms have been shown to provide more opportunities for classroom interaction (Bergmann & Sams, 2012), have a positive impact on students' conceptual understanding of mathematics (Y. Chen et al., 2017), and provide opportunities for students to improve their critical thinking skills through active learning during class sessions (Zainuddin & Halili, 2016). Furthermore, recent developments have shown that the integration of personalized learning paths, peer collaboration, social learning strategies, and advanced technology tools has further amplified the benefits of flipped classrooms (Zhang et al., 2024). These enhancements reflect the ongoing evolution of the flipped classroom to meet diverse learner needs in increasingly digital and collaborative learning environments.

In the post-pandemic period (2022–2024), flipped classrooms have garnered increased attention as educators seek to optimize blended learning methods. Research during 2022–2024 has particularly focused on the adaptation of flipped classrooms to address educational challenges and gaps exacerbated by the pandemic. Studies have demonstrated how flipped and blended learning models can enhance student motivation, reduce cognitive load, and improve mathematical creative thinking skills (Tabieh & Hamzeh, 2024; Ünal et al., 2024). These pedagogical responses aim to address educational gaps that were intensified during the pandemic and to develop future-ready instructional strategies.

It is essential to map the research landscape of flipped classroom applications in mathematics education following COVID-19. The mapping helps not only in understanding academic interests but also in identifying thematic in response to educational disruptions. . Through bibliometric analysis, researchers, educators, and policymakers can gain valuable insights into the evolution of this field, allowing them to

refine future strategies based on evidence-based practices (Maulidiya & Aziza, 2024; Mukherjee et al., 2022). Previous studies have conducted extensive bibliometric analyses of flipped classrooms in 2012 - 2022, highlighting significant research collaborations across regions and thematic trends, particularly in medical education (Zhang et al., 2024). The identifying key themes and shifts within the field, this study provides a foundation for understanding how educational strategies have adapted to post-pandemic challenges. The insights gained will contribute to ongoing discussions on pedagogical innovation, ensuring that flipped classrooms continue evolving to meet the specific demands of mathematics education.

Given this progress, it is critical to explore how the scientific discourse on flipped classrooms in mathematics education has changed in the post-pandemic era. This study aims to find new themes, changes in pedagogical goals, and technological integrations that represent teachers' reactions to pandemic-related disruptions by concentrating on the years 2022–2024. This study uses a bibliometric approach to analyze the trends, clusters, and directions that characterize the current state of flipped classroom research in mathematics, rather than just cataloguing previous articles. Bibliometric methods enable researchers to explore the structure, development, and dissemination of knowledge in a particular field using quantitative techniques (Aria & Cuccurullo, 2017). In order to direct future innovations, educational policy needs to be made, and ensure that the lessons acquired from the pandemic are effectively incorporated into long-term teaching practices. Therefore, it is essential to comprehend these tendencies. The current study develops three particular research questions to direct this examination and comprehend the current trajectory of flipped classroom research in mathematics education during the post-pandemic period (2022–2024). Specifically, this study seeks to address the following questions.

1. How have patterns of author collaboration and institutional networks evolved in flipped classroom research during the post-pandemic period?
2. Which journals and publication sources have most significantly contributed to flipped classroom research in mathematics education post-pandemic, and what trends can be observed regarding publication impact and accessibility?
3. What are the dominant thematic trends in flipped classroom research in mathematics education between 2022 and 2024, and how do these reflect post-pandemic educational priorities?

Through these questions, this study aims not only to map the bibliometric landscape of flipped classroom research in mathematics education but also to uncover the intellectual, collaborative, and thematic shifts that have characterized the field during the post-pandemic period. Specifically, it seeks to identify how flipped classroom practices have evolved in response to educational disruptions, how collaboration patterns have developed across regions and institutions, and how knowledge dissemination has been shaped by the influence of key journals. The insights derived from this analysis are expected to guide future research agendas, promote inclusive and interdisciplinary collaboration, and support evidence-based innovations in mathematics instruction through flipped learning models.

Method

A bibliometric analysis was conducted to map the research landscape of flipped classrooms in mathematics education between 2022 and 2024. Initially, the ERIC database was utilized to identify relevant scholarly articles. The collected data was then organized and managed using Zotero. Subsequently, key features from these articles were extracted and analyzed using bibliometric software, Biblioshiny, to identify trends, patterns, and the most influential authors, journals, and keywords in the field (Aria & Cuccurullo, 2017). The research process, adopted from Maulidiya and Aziza (2024), involves five stages as as visualized in Figure 1. The steps include: (1) defining the problem and research goals, (2) identifying relevant literature through the ERIC database, (3) organizing and managing the metadata using Zotero, (4) extracting bibliographic features via Bibliometrix, and (5) conducting performance analysis and co-word mapping to uncover patterns related to the research questions.

Figure 1. Research Procedure (Maulidiya & Aziza, 2024)

The initial stage of this research is to identify relevant data sources. The study aimed to identify post-pandemic trends in flipped classroom research in mathematics education by analyzing authorship patterns, journal contributions, and thematic development from 2022 to 2024. In this case, the ERIC (Education Resources Information Center) database was chosen as the main source. ERIC is a comprehensive and reliable

database for research in the field of education, especially related to mathematics learning (Maulidiya & Aziza, 2024).

Research data was obtained through a search for relevant keywords in the ERIC database and restricted to peer-reviewed journal articles. The keywords used include a combination of "flipped classroom", "mathematics education", and publication year limits, namely after 2021 and before 2025. Articles that meet the inclusion criteria are then downloaded and stored in digital format in the form of enbib files.

The data that has been collected is then organized using the Zotero reference software. The bibliographic records exported from ERIC were in .nbib format. Due to compatibility limitations with Mendeley, Zotero was used to import, organize, and clean the data. Zotero enabled accurate metadata extraction and conversion to BibTeX format, which was required for further analysis. Zotero allows researchers to manage, classify, and tag the articles that have been collected. In addition, Zotero also facilitates the process of extracting bibliographic data such as title, author, year of publication, journal, and abstract.

After the data is organized, the next stage is feature extraction. The features extracted include keywords, author names, journal titles, publication years, and institutional affiliations. This data is then converted into a format that can be read by bibliometric analysis software. The results of data cleaning are stored in BibTex files.

The cleaned BibTeX data reveals that the study comprehensively analyzed 253 relevant publications, involving 154 different sources, and contributed by 733 authors. This broad data coverage allows for an in-depth picture of the flipped classroom research landscape in mathematics learning. The extracted data was then analyzed using bibliometric analysis software. In this study, Biblioshiny, the graphical interface of the Bibliometrix R package, was used that allows researchers to analyze author and journal productivity and keyword networks (Aria & Cuccurullo, 2017)

Results and Discussion

This section presents the findings of the bibliometric analysis conducted on 253 journal articles related to flipped classroom research in mathematics education from 2022 to 2024. The discussion is organized according to the three research questions.

RQ1: How have patterns of author collaboration and institutional networks evolved in flipped classroom research during the post-pandemic period?

The graphs and tables in this section was analyzed and interpreted to reveal interesting patterns in flipped learning research in mathematics. Figure 2 is the visualization showing the most prolific authors in flipped classroom research from 2022 to 2024. Each bar represents the number of articles published by the respective author.

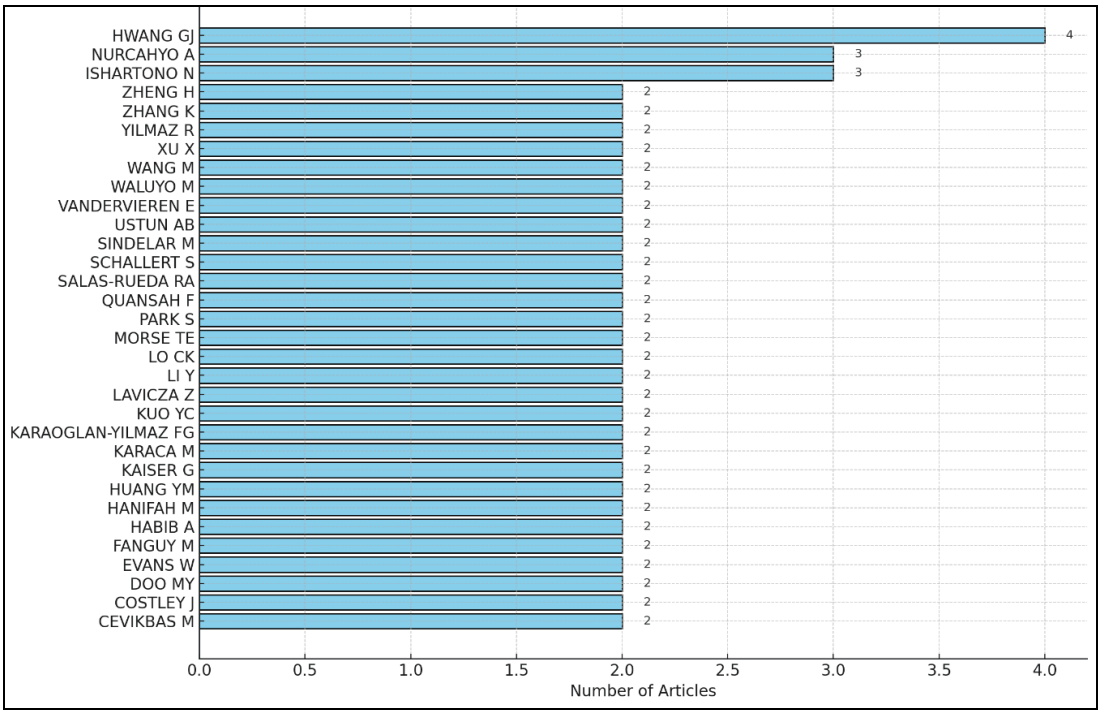

Figure 2. Most Relevant Authors in Flipped Classroom Research (2022 – 2024)

The publication data indicates a notable disparity in research output among the authors. A small group of researchers significantly influence the research output in a specific field, with only a few notable contributions from Gwo-Jen Hwang (four publications), Naufal Ishartono, and Adi Nurcahyo (each with three publications). Most authors (96%) have only one publication, indicating a research concentration among a few key individuals. This disparity in research output and involvement in the field suggests significant variation in the participation of authors. However, international co-authorship remains sparse, and most collaborations were regional.

The table 1 shows a list of publications by Gwo-Jen Hwang, Naufal Ishartono, and Adi Nurcahyo, identified as top authors in the field of flipped classroom research.

Table 1. Publications by Top Authors

Author	Years	Titles	Journals
Gwo-Jen Hwang	2024	Facilitating Efl Learners' Willingness to Communicate Amidst the Pandemic: A Digital Storytelling-Based Online Flipped Learning Approach (Luan et al., 2024)	Innovation in Language Learning and Teaching
	2022	Findings and Implications of Flipped Science Learning Research: A Review of Journal Publications (C. K. Chen et al., 2022)	Interactive Learning Environments
	2022	A Concept Mapping-Based Prediction-Observation-Explanation Approach to Promoting Students' Flipped Learning Achievements and Perceptions (Hwang et al., 2022)	Educational Technology Research and Development
	2022	Advancement and the Foci of Investigation of Moocs and Open Online Courses for Language Learning: A Review of Journal Publications from 2009 to 2018 (Fang et al., 2022)	Interactive Learning Environments
Naufal Ishartono & Adi Nurcahyo	2022	Integrating Geogebra into the Flipped Learning Approach to Improve Students' Self-Regulated Learning During the Covid-19 Pandemic (Ishartono, Nurcahyo, Waluyo, Prayitno, et al., 2022)	Journal on Mathematics Education
	2022	Geogebra-Based Flipped Learning Model: An Alternative Panacea to Improve Students' Learning Independence in Online Mathematics Learning (Ishartono, Nurcahyo, Waluyo, Razak, et al., 2022)	Journal of Research and Advances in Mathematics Education
	2022	Employing Powerpoint in the Flipped-Learning-Based Classroom to Increase Students' Understanding: Does It Help? (Ishartono, Nurcahyo, Sufahani, & Afiyah, 2022)	Asian Journal of University Education

Gwo-Jen Hwang has published four articles across different years, with a focus on various aspects of flipped learning, including its impact on language learning, science learning, and MOOCs. These works were published in prominent journals such as Innovation in Language Learning and Teaching, Interactive Learning Environments, and Educational Technology Research and Development. On the other hand, Naufal Ishartono and Adi Nurcahyo have co-authored three articles in 2022, focusing on the integration of Geogebra and PowerPoint into flipped learning to improve self-regulated learning and understanding in mathematics education. Their publications, featured in journals like Journal on Mathematics Education, Journal of Research and Advances in Mathematics Education, and Asian Journal of University Education, highlight their significant contribution to enhancing mathematics education during the COVID-19 pandemic. These publications underscore the growing importance of flipped learning in the context of online and blended learning environments.

Therefore, it is important to further examine the collaboration between authors, given that many authors have contributed two articles, indicating the potential for collaborative networks that could enrich research in the field of flipped classroom

mathematics education (Figure 3). Understanding these collaborations is essential to uncovering the patterns of cooperation that may influence the quality and direction of research in this area.

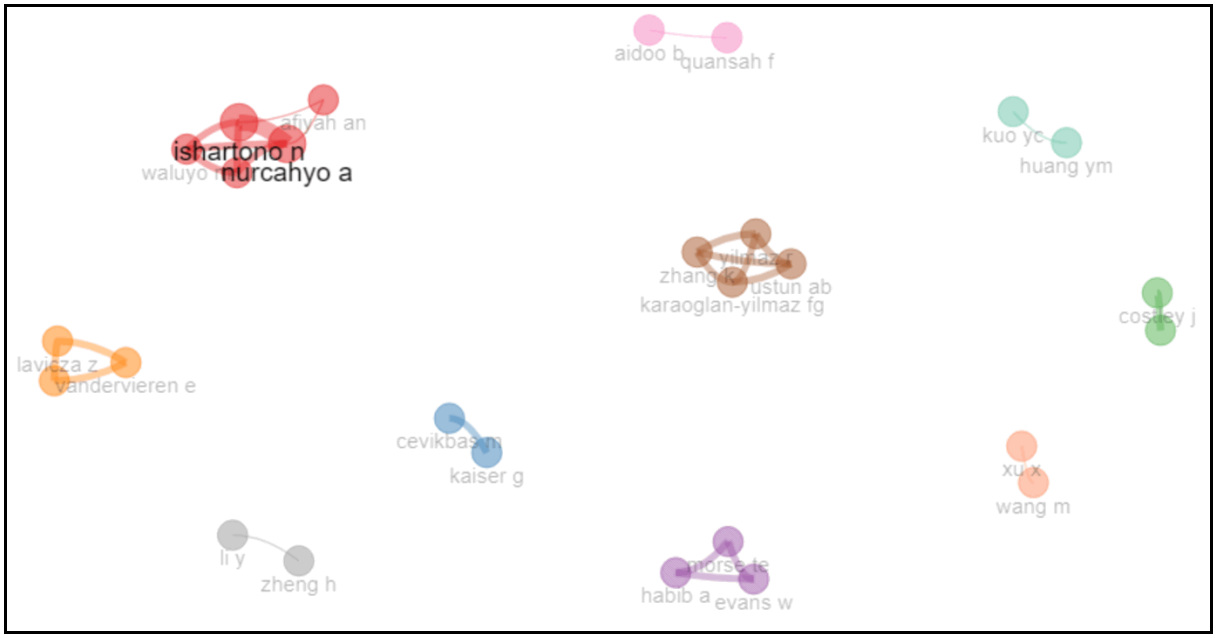

Figure 3. Collaboration Network of Authors

The collaboration network of authors highlights the grouping of researchers into clusters based on their collaborative patterns in flipped classroom research. Authors like Ishartono N, Nurcahyo A, Hanifah M, and Waluyo M are part of Cluster 1, suggesting strong collaboration, particularly in mathematics education using Geogebra and PowerPoint. Similarly, researchers such as Cevikbas M and Kaiser G in Cluster 2 and Costley J and Fanguy M in Cluster 3 likely focus on different domains of flipped learning. Clusters also indicate distinct research focuses, with clusters 4 (Evans W, Habib A, Morse TE) and cluster 6 (Karaoglan-Yilmaz FG, Ustun AB, Yilmaz R, Zhang K) potentially representing thematic or regional collaboration trends. For example, Cluster 9 (Huang YM and Kuo YC) may represent research in flipped learning and technology in education. The collaboration network reveals distinct patterns of cooperation among authors, where researchers are grouped into clusters that likely reflect thematic, methodological, or regional focuses (Mukherjee et al., 2022). The network's structure underscores the potential for cross-cluster collaborations to bridge thematic or methodological gaps, enriching the flipped classroom research field further.

These findings suggest that although flipped classroom research is active, especially in Southeast Asia, it still lacks strong inter-institutional and interdisciplinary collaboration. This gap highlights the need for broader international networking and research funding strategies to promote cross-border initiatives and knowledge sharing in mathematics education.

RQ2: Which journals and publication sources have most significantly contributed to flipped classroom research in mathematics education post-pandemic, and what trends can be observed regarding publication impact and accessibility?

Top journal characteristics and their influence on flipped classroom research in mathematics education were obtained by analyzing 253 documents, revealing that 154 different sources have contributed to flipped classroom research in mathematics learning.

Table 2. Top Journals Publishing Flipped Classroom Research in Mathematics Education

Source	Total Articles	H-Index	Country	Quartiles
Interactive Learning Environments	31	68	United Kingdom	Q1
Education and Information Technologies	24	76	United States	Q1
International Journal of Mathematical Education in Science and Technology	22	42	United Kingdom	Q1
Journal of Computer Assisted Learning	12	114	United Kingdom	Q1
Anatomical Sciences Education	9	71	United States	Q1
Australasian Journal of Educational Technology	4	68	Australia	Q1
Journal of Applied Research in Higher Education	4	25	United Kingdom	Q2
Primus	4	25	United Kingdom	Q3

The journals listed in the table 2 represent prominent platforms for disseminating research on flipped classrooms, reflecting diverse characteristics in terms of article volume, H-index, country of origin, and quartile ranking. Journals like Interactive Learning Environments and Education and Information Technologies stand out with the highest H-index values (68 and 76, respectively) and substantial article contributions, indicating their critical role in shaping the field. Their Q1 quartile ranking reflects a focus on high-quality, impactful research, which may drive innovation and establish best practices in flipped classroom methods globally.

Journals such as Anatomical Sciences Education and Australasian Journal of Educational Technology cater to specific domains or regions, reflecting the adaptability of flipped classroom methodologies in varied educational contexts. These journals provide

niche insights, such as flipped approaches in science education or technology-enhanced learning in Australasia, highlighting regional applications and challenges.

Primus and Journal of Applied Research in Higher Education, despite having lower H-index values (25), contribute meaningfully to flipped classroom research by publishing practical applications and exploratory studies. Their Q2 and Q3 quartile rankings suggest an emphasis on innovative but less mainstream methodologies, offering a space for experimental research.

The majority of high-impact journals are based in the United Kingdom and the United States, indicating their central role in influencing global flipped classroom research trends. This geographical concentration suggests that researchers in other regions may face challenges in accessing these prestigious journals, potentially creating disparities in global research representation (Donthu et al., 2021). The diverse characteristics of these journals underline their collective influence on flipped classroom research, ranging from foundational studies in high-impact outlets to exploratory works in mid-tier journals. This ecosystem fosters both theoretical advancements and practical innovations, though more balanced global representation may further enrich the field.

RQ3: What are the dominant thematic trends in flipped classroom research in mathematics education between 2022 and 2024, and how do these reflect post-pandemic educational priorities?

The exploration of interconnections among keywords in flipped classroom studies was conducted using a co-occurrence network of Keyword Plus terms (Figure 4). These Keyword Plus terms were derived from Descriptors in the ERIC Thesaurus, which are words or phrases representing subjects within the field of education. Descriptors are employed to index ERIC records, and every record in ERIC contains these descriptors. In total, 707 Keyword Plus terms were extracted, with a cumulative frequency of 2,956, highlighting the breadth and interconnectedness of topics related to flipped classroom research. To gain deeper insights into these interconnected topics, a co-occurrence network analysis was conducted, identifying thematic clusters that reveal the relationships and focal points of research in this area (Donthu et al., 2021; Mukherjee et al., 2022). These clusters serve as a lens to understand the dominant themes and contextual factors shaping flipped classroom practices. The co-occurrence network analysis of Keyword Plus terms revealed two distinct yet interconnected clusters within the flipped classroom research landscape (Figure 4).

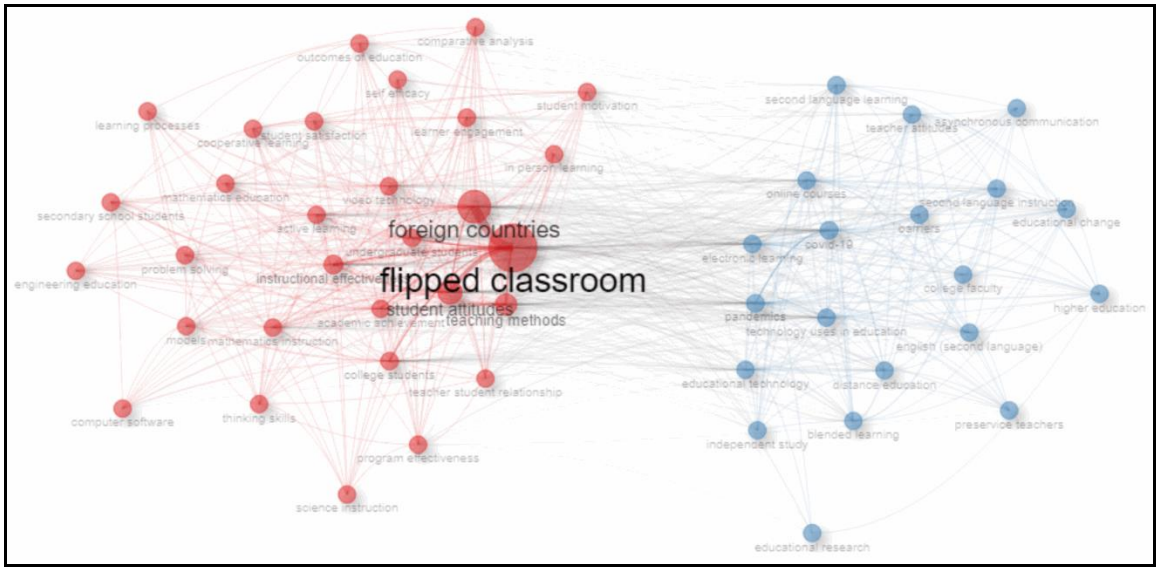

Figure 4. Co-occurence Network of Keyword Plus

The first cluster, namely Core Pedagogical Themes, primarily focuses on pedagogical aspects central to flipped classroom implementation. The keyword "flipped classroom" acts as the hub, with the highest centrality metrics, connecting terms such as "student attitudes", "teaching methods", and "instructional effectiveness". These terms emphasize the influence of flipped classrooms on learner perceptions, instructional approaches, and measurable outcomes (Luan et al., 2024). Additionally, descriptors like "academic achievement", "college students", and "active learning" reflect the focus on higher education students and the active engagement strategies enabled by this approach (C. K. Chen et al., 2022). Specific applications, such as "mathematics instruction" and "video technology", further illustrate how flipped classrooms are tailored to certain disciplines and technological tools (Hwang et al., 2022) . The core pedagogical themes, emphasizing student engagement, effective teaching methods, and measurable outcomes as the impact of flipped classrooms.

In contrast, the second cluster, namely Technology and Contemporary Challenges, shifts attention to the role of technology and external challenges in flipped classroom research. Keywords such as "COVID-19" and "pandemics" highlight the pivotal role of global crises in accelerating the adoption of technology-enhanced learning(Luan et al., 2024). Related terms like "electronic learning", "educational technology", and "online courses" underscore the growing reliance on digital platforms in delivering flipped classroom experiences (C. K. Chen et al., 2022). At the same time, descriptors such as "barriers" and "blended learning" point to both the challenges and opportunities associated with integrating technology into traditional pedagogical frameworks (Hwang et al., 2022).

The second cluster highlighted the significant influence of technology and contemporary challenges, particularly the COVID-19 pandemic, on the evolution of flipped classroom practices. This cluster reflects a dynamic interplay between innovation and adaptability in the face of evolving educational demands. This cluster also reflects the increasing reliance on digital tools, online platforms, and blended learning approaches in contemporary educational settings.

The insights derived from the cluster analysis align closely with the focus areas highlighted in the works of top authors in flipped classroom research. The first cluster, which emphasizes pedagogical themes such as "teaching methods", "student attitudes", and "active learning", mirrors the core interests of authors exploring the effectiveness of flipped classroom models in enhancing learner engagement and academic outcomes (Fang et al., 2022). Similarly, the second cluster, which focuses on technological integration and challenges like "COVID-19" and "blended learning", resonates with research by leading authors addressing the role of digital tools and online platforms in adapting to global disruptions and advancing innovative teaching strategies (Ishartono, Nurcahyo, Waluyo, Prayitno, et al., 2022). This thematic alignment between the network analysis and top author contributions underscores the synergy between conceptual trends and empirical findings in the flipped classroom literature. The insights gleaned from this network analysis provide a valuable overview of the key themes and interconnected concepts driving flipped classroom research in mathematics education, offering a foundation for future research and innovation in this dynamic field. These trends suggest that flipped classroom research in the post-pandemic context is not only responding to emergency digitalization but is actively innovating pedagogical practices for long-term blended learning success in mathematics education.

Conclusion and Suggestion

This bibliometric study examined the evolution of flipped classroom research in mathematics education during the post-pandemic period (2022–2024). The findings reveal three major developments.

First, collaboration patterns remain predominantly local or regional, with limited international and inter-institutional networks. This highlights the need to strengthen global research collaboration, not only to foster cross-border knowledge exchange but also to build a more inclusive and decentralized research ecosystem. While flipped classroom

research continues to thrive—particularly in Southeast Asia—its limited global integration underscores the importance of broader networking initiatives and sustainable funding strategies.

Second, publication sources are largely dominated by high-impact journals from the Global North. However, emerging journals from Southeast Asia and the Middle East are increasingly contributing to the discourse, signaling a dual trend of centralization and diversification in research dissemination. Despite this progress, disparities in visibility, accessibility, and impact persist, presenting ongoing challenges for equitable advancements in mathematics education.

Third, the study identified two dominant thematic clusters within the literature. The first cluster, Core Pedagogical Themes, reflects a sustained emphasis on designing interactive, student-centered instructional models—an approach particularly vital in mathematics education, where conceptual understanding and critical thinking are key. The second cluster, Technology and Contemporary Challenges, captures the transition of flipped classrooms into hybrid and technology-enhanced learning environment, particularly in response to the COVID-19 pandemic. Keywords like "electronic learning," "online courses," and "blended learning" have gained prominence, reflecting the shift towards integrating technological solutions in response to pandemic-era educational disruptions to address future educational challenges.

Across all three dimensions—collaboration, publication, and theme—the findings show that flipped classroom research has become more diverse, tool-integrated, and pedagogically reflective post-pandemic. However, there remain significant gaps in global collaboration and equitable access to high-impact dissemination channels.

Consequently, to advance the field of flipped classroom research, several strategies should be considered. Encouraging collaboration among researchers, particularly between established scholars and emerging researchers, can broaden research participation and ensure a more equitable distribution of research contributions. Diversifying funding sources and promoting open access to research publications can enhance the dissemination of findings and facilitate global knowledge sharing. Exploring interdisciplinary approaches across various disciplines, such as education, technology, and psychology, can lead to more innovative and impactful research outcomes.

This study presents a structured overview of flipped classroom research in mathematics education during the post-pandemic period, revealing shifts in collaboration

networks, publication trends, and thematic focus. While regional engagement and pedagogical innovation are on the rise, challenges persist in global collaboration and equitable dissemination. These insights provide a foundation for advancing more inclusive, interdisciplinary, and responsive research to meet the evolving needs of mathematics education.

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