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GLOBAL TRENDS IN FLIPPED CLASSROOM RESEARCH WITHIN MATHEMATICS EDUCATION OVER PAST TWO DECADE: A BIBLIOMETRIC ANALYSIS

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ABSTRACT

This research aims to provide a bibliometric review of trends in using flipped classrooms in mathematics learning research. This research is essential to analyze the extent of the flipped classroom research trend in mathematics learning as a reference for future research in this research. Bibliometric analysis was used to analyze and classify bibliographic data by considering inclusion and exclusion criteria. The database used was Scopus using the Bibliometrix application. The search was carried out using the keywords "flipped classroom", "mathematics learning", and "K-12". The results revealed a total of 102 articles related to the keywords. The data showed increased publications over the last two decades, with 2023 being the year with the highest publication count. Apart from that, Indonesia had the highest rate of producing related articles. The most relevant author was Hew Khe Foon. The most cited article was "A self-regulated flipped classroom approach to improving students' learning performance in a mathematics course". The Indonesian Education University was the most productive affiliate related to this theme. Furthermore, the journal "Educational Technology and Society" was found to be the most prolific journal for publishing research outcomes. New themes emerged in flipped classroom research, such as conceptual and procedural knowledge. Future researchers are expected to utilize the research focus to determine the theme to be explored. It is recommended that further researchers incorporate the novelty discussed in this research.

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1. INTRODUCTION

A flipped classroom can be seen as a teaching approach that switches the learning tasks, where activities usually done in class might be assigned as homework and the other way around (Lo & Hew, 2017c). A flipped classroom can be seen as a teaching approach that switches the learning tasks, where activities usually done in class might be assigned as

homework and the other way around. According to Bergmann and Sams (2012) the flipped classroom involves swapping the material traditionally taught in class to be learnt independently at home, while the tasks traditionally designated as homework are now addressed during class time.

The term flipped classroom is often confused with flipped learning even though the two terms are different. While it's often defined simply as "school work at home and homework at school," flipped learning can be viewed as an approach that allows teachers to apply various methodologies in their classrooms. To address some misconceptions about this term, the governing board and key leaders of the Flipped Learning Network (FLN), who are experienced flipped educators, have created a formal definition of "flipped learning." Clearly defining the term might help dispel myths that are frequently spread by teachers, the media, and researchers. These leaders also differentiate between a flipped classroom and flipped learning. These terms are not the same. Flipping a class might, but does not necessarily, lead to flipped learning. Many teachers may already flip their classes by having students read text outside of class, watch supplemental videos, or solve additional problems, but to truly engage in flipped learning, teachers need to incorporate the following four pillars into their practice (Yarbro et al., 2014). Flipped Learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter (Flipped Learning Network (FLN), 2014).

The flipped classroom model has been widely used recently because it has been proven to increase student motivation and involvement in learning (Demir et al., 2023; Nadarajan et al., 2023). According to Nouri (2016), most students responded positively to the flipped classroom model because it involved learning videos and the Moodle platform. This positive reception is closely related to increased motivation, engagement levels, and improved learning experiences.

Mathematics is a crucial field in the progress of science and technology. Mathematics is studied at almost every level of education (Hidayat & Aripin, 2023). The flipped classroom approach in K-12 mathematics education involves delivering teacher lectures through online videos before class, allowing in-class time for active learning and problem-solving activities (Lo & Hew, 2016). Research has shown that the majority of studies on flipped learning in K-12 have focused on student perceptions and achievement within STEM subjects, particularly mathematics, indicating a preference for quantitative methods (Bond et al., 2020). The implementation of the flipped classroom in mathematics has led to improvements in students' knowledge and attitudes toward mathematical content and discipline (Fernández-Martín et al., 2020).

Based on search results in the Scopus database, several studies have shown that the flipped classroom model can positively influence attitudes toward learning, specifically benefiting students who have difficulty following the learning formats. Nielsen (2020) highlighted the potential of the flipped classroom in promoting engaging learning environments for such students.

Moreover, other findings suggest that the flipped classroom contributes to improved outcomes, self regulation learning and social interactions among students compared to teaching approaches. Jdaitawi (2019) observed levels of self regulation and social engagement in students within a flipped classroom setting. Additionally, this educational model has been linked with advancements in student achievements, motivation levels and overall satisfaction with their learning experiences.

Kolomiets et al. (2020) found that the main advantage of implementing the flipped classroom method in teaching English as a language is its impact on students' academic

performance, leading to increased motivation and satisfaction levels. The flipped classroom model is widely recognized as an approach to learning for engaging students in interactive and meaningful educational experiences. Fauzi (2019) highlighted the advantages associated with the flipped classroom, underscoring its effectiveness in fostering learning outcomes.

This approach involves reversing the traditional method of information presentation and application activities, leading to improved student engagement, interaction, and higher-order thinking skills (Pattiserlihun & Setiadi, 2020; Ying & Mohd Ayub, 2022). The flipped classroom has been found to promote student-centered learning experiences, increase student activity and interaction, and enhance student responsibility and learning outcomes (Nurpratiwi et al., 2021; Urquiza-Fuentes, 2020). Additionally, it has been associated with improved student diversity in belief, practice, and knowledge dimensions in religious education (Stöhr & Adawi, 2018). The model has roots in constructivist and social-constructivist perspectives on learning, emphasizing the active role of the learner in constructing knowledge and the importance of scaffolding by teachers and peers (Gok & Bozoglan, 2016). Overall, the flipped classroom is seen as a promising approach that can transform the traditional classroom into a more engaging and student-centered learning environment.

The flipped classroom has gained popularity in K-12 education, with studies exploring its implications for students with learning and behavioral challenges (Morse et al., 2022). Teacher perceptions regarding the flipped classroom model for teaching and learning in K-12 settings have been investigated, shedding light on its implementation and effectiveness (Gough et al., 2017). Additionally, the flipped classroom has been found to promote independent learning, improve learning awareness, and support students' mathematical thinking and understanding through differentiated teaching strategies (Schallert, 2021; Umam et al., 2019). Furthermore, the flipped classroom has been associated with improved student achievement and satisfaction in mathematics learning (Fatimah et al., 2022; Makinde, 2020). Implementing the flipped classroom model in K-12 education is essential for fostering a more engaging and effective learning environment across elementary, middle, and high school levels. In K-12 settings, this method promotes student-centered learning from an early age, encouraging critical thinking, problem-solving, and collaboration among students at all grade levels. Therefore, it is necessary to carry out a more specific bibliometric analysis involving K-12 level variables

Similar studies regarding bibliometrics that focus on the flipped classroom have been studied, some of them by Sihotang et al. (2023) who researched using bibliometric studies to analyze flipped classroom research trends in mathematics learning from 2016-2021. This research found an increase in research trends regarding the flipped classroom from year to year, the most popular proceedings and journals, as well as the years with the most publications regarding the flipped classroom. Another bibliometric research was carried out by del Arco et al. (2022) which identifies the main existing trends and emerging strategic research paths in relation to the Flipped Classroom pedagogical model. Apart from that, other research by Soebagyo and Saamah (2023) examines the potential for future research related to the flipped classroom. From this description, many bibliometric studies have been carried out, but they have not touched on the analysis of flipped classrooms for K-12 levels in mathematics learning until 2024 and have not yet explained in detail research trends by analyzing the most relevant authors, most relevant sources, most cited articles, countries. produced the most articles and affiliates produced the most articles about the flipped classroom in mathematics learning.

Therefore, the general aim of this research is to analyze the growth trend of the flipped classroom from 2004 to 2024. Specifically, the aim of this research is to analyze articles regarding the flipped classroom in mathematics learning for k-12 levels from the

aspects of 1) the most relevant author, 2) the most relevant source, 3) the most cited article, 4) the highest affiliation in produces articles, 5) the country that produces the most articles and 6) Potential for future research. A bibliometric analysis was carried out using Bibliometrix software with the R programming language on data collected using the Scopus database. It is hoped that this research can help and become a reference for other researchers when deciding on a research theme.

2. METHOD

This research uses data from published articles that have been published in Scopus indexed journals. The reason for using Scopus is because Scopus delivers smart tools to track, analyze, and visualize research. Moreover, daily data updates make it possible to obtain up-to-date and reliable data (Wan et al., 2019). Therefore, we chose this for bibliometric research. In this study, each article that was filtered was only articles related to flipped classroom mathematics learning in K-12, which collected 102 articles from 2004-2024. Data was obtained through searching the Scopus database with the keywords ("flipp* classroom" OR "blend* learning") AND ("math*") AND ("secondary school" OR "Primary school" OR "Elementary school" OR "Middle school " OR "High school") where this word is adjusted to the criteria of title, keywords and abstract.

The data that has been obtained is exported in BibTeX bibliographical database file (*.bib) format and comma separated value (*.csv) format. File storage in the form of *.bib is used to process article metadata consisting of author name, title, year, journal name, publisher, number of citations, article links and related URLs using Microsoft Excel. Files in the form *.bib are used to carry out mapping using Bibliometrix, because only files in the form *.bib or *csv can be read by Bibliometrix. Next, analysis was carried out using Bibliometrix to visualize and analyze bibliometric maps (Supriyadi et al., 2023). The process of document selection using the PRISMA (Page et al., 2021) protocol is presented systematically in Table 1.

Table 1. Search protocol

Aspect	Description
Study Period	2004-2024
Database	Scopus
Keyword	("flipp* classroom" OR "blend* learning") AND ("math*") AND ("secondary school" OR "Primary school" OR "Elementary school" OR "Middle school " OR "High school")
Inclusion Criteria	1. Journal articles 2. Article in English
Exclusion criteria	1. Book, Conference Proceedings, Book Chapters, or other type of publications 2. articles that are not in English

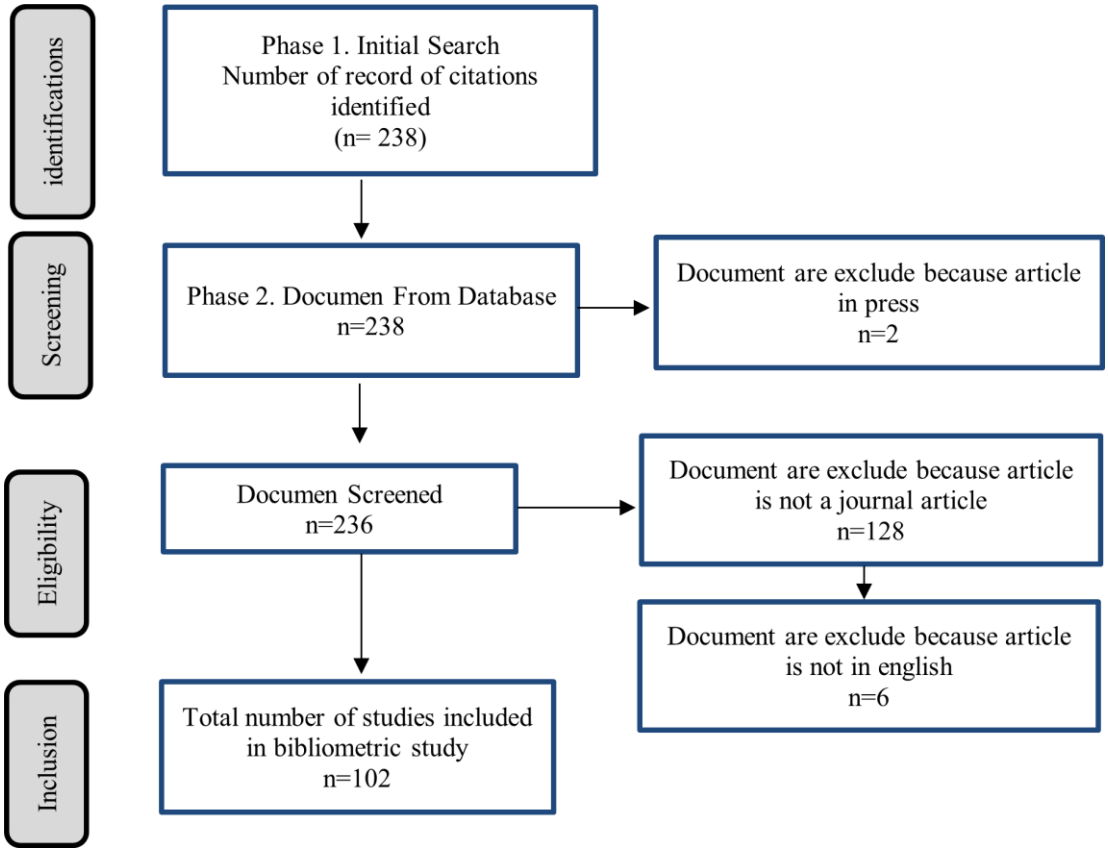

Figure 1. PRISMA flowchart

Based on Figure 1, there are 102 articles that will be analyzed further with Bibliometrix. Bibliometrix was chosen to visualize and analyze trends in the form of bibliometric maps. Data mapping articles from the Scopus database are presented on Bibliometrix with three types of mapping, namely network visualization, density visualization, and overlay visualization, but in this research only network visualization based on keywords was chosen (Aria & Cuccurullo, 2017).

3. RESULT AND DISCUSSION

3.1. Results

The topic of "flipped classroom in mathematics learning in K-12" draws from a dataset covering the years 2004 to 2024 and includes various publications such as journals and books. This analysis highlights several key aspects of the research in this area (Table 2).

Table 2. Information about data

Type	Description	Results
Main Information	Timespan	2004:2024
	Sources (Journals, Books, etc)	69
	Documents	102
	Annual Growth Rate %	10.58
	Document Average Age	4.2
	Average citations per doc	24.64
	References	0

Type	Description	Results
Document Contents	Keywords Plus (ID)	132
	Author's Keywords (DE)	344
Authors	Authors	297
	Authors of single-authored docs	8
Author Collaboration	Single-authored docs	9
	Co-Authors per Doc	3.12
	International co-authorships %	17.65
Documen Types	Article	102

The dataset comprises 102 documents sourced from 69 different journals and books, indicating broad interest across various platforms (see Table 2). This diversity in sources demonstrates the wide acceptance and investigation into the flipped classroom methodology within the academic community. An annual growth rate of 10.58% is observed, suggesting a steadily increasing interest in the flipped classroom approach, particularly within K-12 mathematics education.

The average age of these documents is approximately 4.2 years, indicating that the majority of the research is relatively recent and may still be highly relevant to current educational practices. A notable finding is the high average citation count per document, which stands at 24.64. This indicates that the work published on this topic has had a significant impact, with each document being frequently cited by other researchers, reflecting the influential nature of these studies.

In terms of collaboration, the data shows that the flipped classroom research is largely a collaborative effort, with 297 authors contributing to the body of work, and only 9 documents authored by single authors. This suggests a strong trend toward collaborative research in this field, which is supported by an average of 3.12 co-authors per document. Additionally, 17.65% of the documents feature international co-authorships, highlighting some level of global collaboration and suggesting an exchange of ideas across different educational and cultural contexts.

All 102 documents in the dataset are articles, emphasizing that the primary mode of dissemination for research in this area is through academic journals. The use of 132 Keywords Plus and 344 Author's Keywords demonstrates the diverse range of focus areas and subtopics explored under the broader theme of flipped classrooms, such as technology integration, pedagogical strategies, and student outcomes.

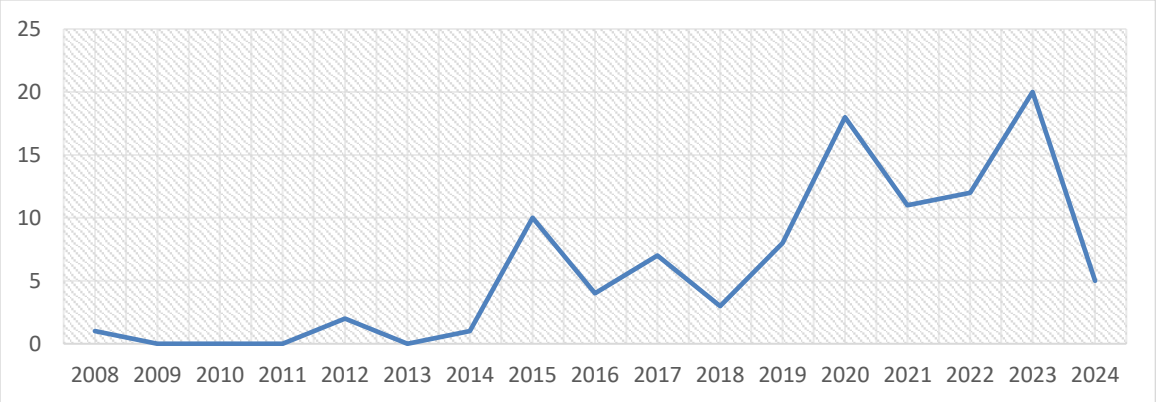

Figure 2. Publications trend of the documents from 2008-2024

Based on Figure 2, we can see that the research trend with the keyword flipped classroom in mathematics and K-12 learning is increasing from year to year, with the peak occurring in 2023 with 20 documents, in 2004-2007 no journal articles were found with the keyword "flipped classroom in mathematics learning in K-12" so in that year range it did not appear in the diagram. This is in line with research del Arco et al. (2022), Sihotang et al. (2023), Tekin and Sarıkaya (2020) who found that research trends regarding the flipped classroom continue to increase from year to year. This shows that the Flipped Classroom has been widely used in mathematics learning, as time goes by the use of technology has become something that must be done, changes in the paradigm of mathematics learning which are usually carried out in class are now starting to change, where mathematics learning can be done independently at home. This trend shows positive opportunities for using blended learning in the future.

3.1.1. Most Relevant Sources

The diverse range of academic journals that have published articles on the topic of the flipped classroom in mathematics learning in K-12, reflecting a multidisciplinary interest in this educational strategy. Leading the list is “Educational Technology and Society” with six publications, indicating its prominent role in exploring the intersection of educational technology with innovative teaching methodologies such as the flipped classroom. This suggests that the journal focuses heavily on how technological advancements can enhance educational practices.

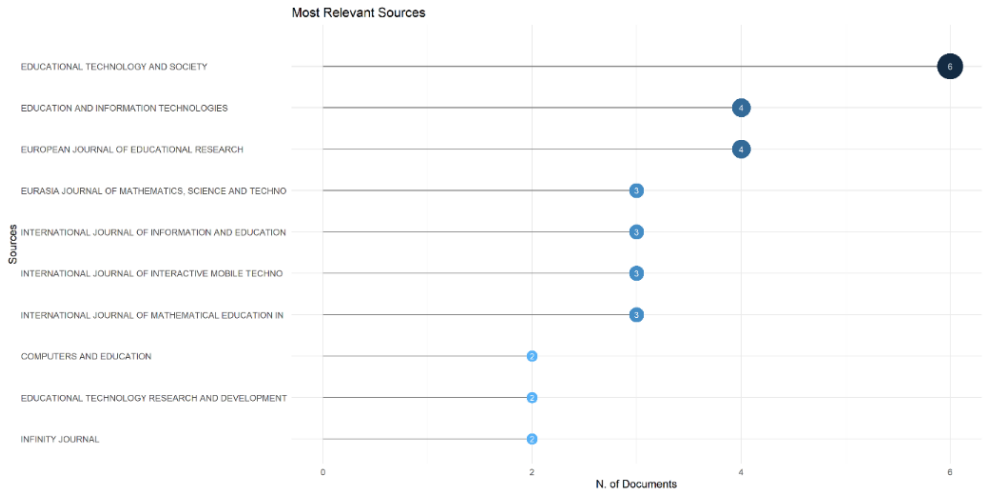

Figure 3. Most relevant sources

Based on Figure 3. Close behind, with four articles each, are “Education and Information Technologies” and “European Journal of Educational Research”. These journals highlight significant interest in technology-enhanced learning and educational reforms within Europe, respectively, showcasing a robust engagement with digital learning environments and their application in education systems.

Several journals, including “Eurasia Journal of Mathematics, Science, and Technology Education”, “International Journal of Information and Education Technology”, “International Journal of Interactive Mobile Technologies”, and “International Journal of Mathematical Education in Science and Technology”, contributed three articles each. This indicates a strong inclination towards integrating mobile and information technologies in mathematical education, underscoring a global trend towards adopting innovative educational technologies.

Journals like "Computers and Education", "Educational Technology Research and Development", and "Infinity Journal", each publishing two articles, also play critical roles but with a more niche focus. These publications highlight the relevance of computing and specific educational theories in enhancing learning experiences and outcomes, particularly in the realm of mathematics.

3.1.2. Most Relevant Author

The concerning authors who have significantly contributed to research on the flipped classroom in mathematics learning in K-12 offers insight into the leading voices and their influence within this educational field. Notably, Hew Khe Foon (Lo & Hew, 2016, 2017a, 2017b), Hwang Gwo-Jen (Hwang & Lai, 2017; Hwang et al., 2019; Lai & Hwang, 2015), and Lo Chung Kwan (Lo & Hew, 2016, 2017a, 2017b) each have authored three articles, positioning them as central figures in the advancement of flipped classroom methodologies (see Figure 4). Their consistent contributions likely encompass a variety of approaches to the flipped classroom, providing a deep dive into both theoretical and practical applications that could be shaping this educational strategy.

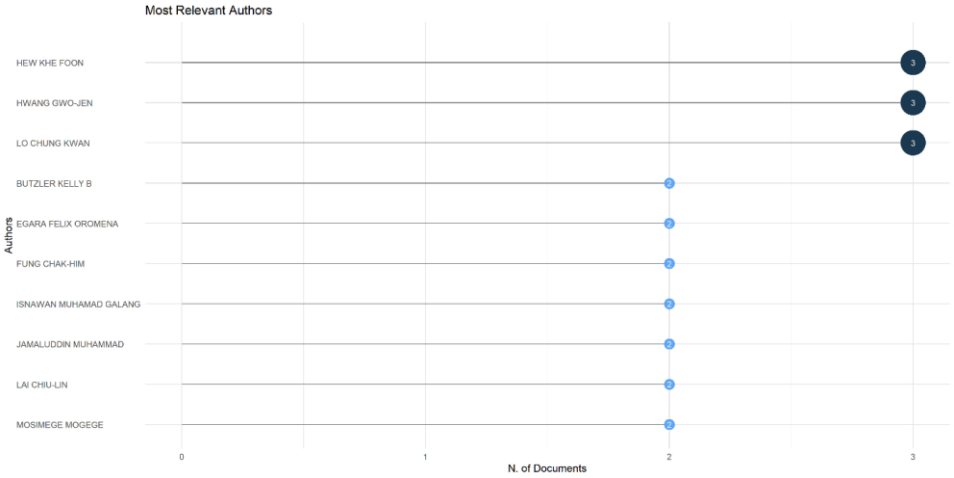

Figure 4. Most relevant authors

Further analysis reveals a group of researchers including Kelly B. Butzler (Butzler, 2015, 2016), Felix Oromena Egara (Egara & Mosimege, 2023, 2024), Chak-Him Fung (Fung, 2020; Fung et al., 2024), Muhamad Galang Isnawan (Isnawan et al., 2023; Isnawan et al., 2022), Muhammad Jamaluddin (Jamaluddin et al., 2023; Jamaluddin et al., 2022), Chiu-Lin Lai (Lai & Hwang, 2015, 2016), and Mogoge Mosimege (Egara & Mosimege, 2023, 2024), each of whom has published two articles. These authors are also pivotal, contributing important perspectives and findings to the discourse, though to a slightly lesser extent compared to the top contributors. Their ongoing research underscores a committed interest in refining and evaluating the flipped classroom approach, particularly within the context of mathematics education for younger learners.

The significance of these contributions cannot be understated, as they likely cover a broad spectrum of topics related to the flipped classroom, from the integration of technology and pedagogical strategies to empirical assessments of learning outcomes. The diversity of these researchers, both in terms of their geographical and academic backgrounds, enriches the global understanding of how flipped classrooms can be effectively implemented in diverse educational settings.

In reporting these findings, it is crucial to emphasize the roles and research areas of these leading authors. Their work serves as a cornerstone for other educators and researchers interested in the flipped classroom, offering a foundation of knowledge and a source of best practices that can influence future educational strategies. Additionally, acknowledging these contributors helps identify networks of scholarly collaboration and areas of expertise, beneficial for new researchers seeking to establish themselves in this field and for practitioners aiming to incorporate evidence-based strategies into their teaching. This analysis is not only valuable for academic purposes but also informs educational policymakers and curriculum developers aiming to leverage robust, impactful research to guide educational innovations.

3.1.3. Most Relevant Affiliation

Data on institutional contributions to research on the flipped classroom in mathematics learning in K-12 highlights significant academic engagement across various global regions, demonstrating the widespread appeal and application of this educational strategy. Notably, Indonesian universities like Universitas Pendidikan Indonesia and Universitas Negeri Yogyakarta lead with seven and five publications, respectively. This indicates a strong focus within Indonesia on exploring and integrating flipped classroom methodologies, positioning these institutions as regional leaders in educational innovation.

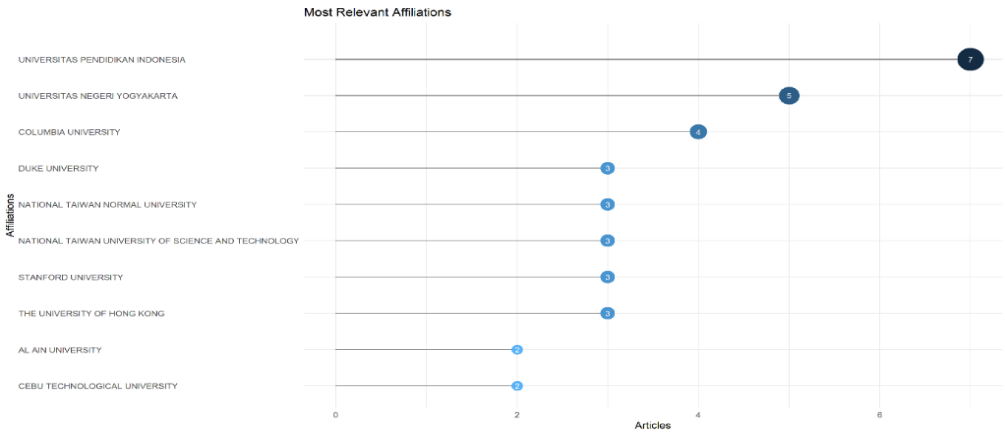

Figure 5. Most relevant affiliation

In the United States, prestigious institutions such as Columbia University, Duke University, and Stanford University have also made notable contributions with four and three articles each (see Figure 5). These contributions reflect a broader trend within Western academia to advance research on educational technologies and innovative pedagogies. Similarly, Taiwan's active participation is evidenced by significant contributions from the National Taiwan Normal University and the National Taiwan University of Science and Technology, each contributing three articles. This involvement suggests a keen regional interest in enhancing STEM education through innovative teaching models.

Additionally, The University of Hong Kong's contribution of three articles emphasizes East Asia's strong focus on educational research, particularly methodologies that integrate technology and active learning. Other institutions such as Al Ain University and Cebu Technological University, with two publications each, further underscore the global interest in flipped classrooms, extending into the Middle East and Southeast Asia, respectively. These varied contributions highlight the adaptability and relevance of flipped classroom strategies across different educational and cultural contexts.

3.1.4. Country scientific Production

The frequency of research publications on flipped classrooms in K-12 mathematics learning by country highlights a significant global interest in this educational strategy. Indonesia emerges as a leader with 43 publications, indicating a strong national focus on enhancing educational methods through flipped classrooms. This is in line with research Faryanti and Efendi (2023) which found that Indonesia is the country with the most publications about flipped classrooms. This substantial involvement suggests that Indonesia is keen on leveraging technological advances and innovative pedagogical approaches to improve its educational systems. Since the outbreak of the COVID-19 pandemic in the world, Indonesia has been affected, especially in the education sector. Blended learning is an alternative during COVID-19. One of the blended learning models used is the flipped classroom which has been proven to be a solution for blended mathematics learning. Therefore, publications in Indonesia are the country with the highest publications related to the flipped classroom topic.

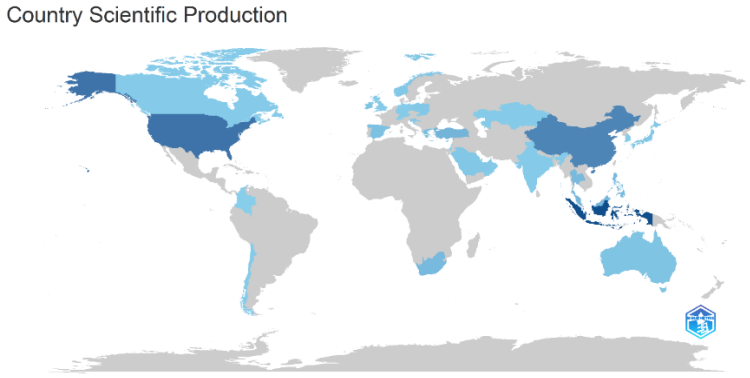

Figure 6. Country scientific Production

Based on Figure 6, following Indonesia, the United States has produced 30 publications, reflecting its ongoing commitment to incorporating new educational technologies and methodologies. The high level of engagement in the US underscores a robust infrastructure for educational research and a readiness to implement innovative teaching strategies aimed at improving student learning outcomes.

Table 3. Country scientific production

Country	Freq
Indonesia	43
USA	30
China	24
Turkey	9
Malaysia	8
Philippines	7
South africa	7
Thailand	7
Greece	6
Spain	5

China, with 24 publications, also shows significant activity in this domain, pointing to its efforts to modernize and enhance its educational practices through technology-enhanced learning environments. This aligns with China's broader educational goals of integrating more interactive and student-centered learning approaches across its schools.

Other countries like Turkey, Malaysia, the Philippines, South Africa, Thailand, Greece, and Spain, though contributing less frequently with between 5 and 9 publications each (see Table 3), still demonstrate a growing interest in flipped classrooms. These contributions reveal a global trend toward exploring how this teaching model can be adapted to diverse educational systems and cultural settings. The geographic distribution of this research underscores the widespread acknowledgment of the potential benefits of flipped classrooms in enhancing mathematics education. The variations in publication frequencies across countries likely reflect different educational priorities, the availability of resources, and the degree of technological integration within each education system. Countries with more publications are likely to have more developed infrastructures for educational technology and a higher propensity for adopting innovative educational strategies.

3.1.5. Most Cited Document

The bibliometric analysis of key publications related to flipped classrooms in K-12 mathematics learning reveals a series of impactful studies that have significantly shaped the academic landscape within this educational strategy. Among these, the paper by Lai and Hwang (2016) published in “Computers & Education”, stands out with an impressive total of 480 citations and an average of 53.33 citations per year (see Table 4), marking it as a cornerstone in educational technology research. This high citation rate underscores its critical insights and enduring relevance to both scholars and practitioners in the field (see Figure 7). The flipped classroom approach correlates with self-regulated learning due to its emphasis on pre-class preparation, which requires students to engage with learning materials independently before class, fostering autonomy and ownership over their learning process (Firdaus et al., 2021; Herutomo & Masrianingsih, 2021; Maolidah et al., 2017; Rahmawati & Nuraeni, 2022; Setiadi, 2021; Yanuarto, 2018).

Figure 7. Most cited document

This approach encourages students to set personal learning goals, monitor their progress, and adjust their strategies as needed, while also promoting active participation in collaborative activities during class time, facilitating communication skills and metacognitive awareness. Additionally, the interactive learning environment of the flipped classroom encourages ongoing reflection and feedback, enabling students to develop self-awareness and critical thinking skills essential for effective self-regulated learning. for that reason, it is only natural that this article is cited the most.

Table 4. Summary most cited document

Paper	Total Citations	Summary
Lai, C.-L., & Hwang, G.-J. (2016). A self-regulated flipped classroom approach to improving students' learning performance in a mathematics course. *Computers & Education, 100*, 126-140.	480	integrating self-regulated strategies into flipped learning can enhance students' self-efficacy and improve their study planning and time management skills, leading to more effective learning and better academic performance.
Grover, S., Pea, R., & Cooper, S. (2015). Designing for deeper learning in a blended computer science course for middle school students. *Computer Science Education, 25*(2), 199-237.	235	The research focused on developing and testing an introductory computer science course for middle school students, "Foundations for Advancing Computational Thinking" (FACT), which aimed to enhance algorithmic problem-solving skills and improve understanding of computing as a discipline, with empirical investigations demonstrating significant learning gains and successful transfer of knowledge from block-based to text-based programming contexts, while identifying factors such as prior computing experience and math ability as strong predictors of learning outcomes
Bhagat, K. K., Chang, C.-N., & Chang, C.-Y. (2016). The impact of the flipped classroom on mathematics concept learning in high school. *Journal of Educational Technology & Society, 19*(3), 134-142.	174	This study aimed to evaluate the impact of the flipped classroom approach on mathematics learning achievement and motivation, utilizing a pretest-posttest quasi-experimental design with 82 high school students. Results indicated a significant difference favoring the flipped classroom in terms of learning achievement and motivation compared to traditional teaching methods
Brahimi, T., & Sarirete, A. (2015). Learning outside the classroom through MOOCs. *Computers in human Behavior, 51*, 604-609.	143	This study explores how MOOCs can be used in high school. While their impact is still uncertain, they offer new ways to learn, especially in subjects like math and science. The study surveyed students at Global International School in Jeddah, showing that many students find learning outside the classroom beneficial.

Paper	Total Citations	Summary
Lo, C. K., Lie, C. W., & Hew, K. F. (2018). Applying "first principles of instruction" as a design theory of the flipped classroom: Findings from a collective study of four secondary school subjects. *Computers & Education*, *118*, 150-165.	112	This research Conducted in two secondary schools with 382 students and five teachers across four subjects, the study refined a flipped classroom model based on a pilot study and evaluated its effectiveness in a main study. Results showed improved student achievement in mathematics, physics, and Chinese language courses after flipping, while outcomes in the ICT course remained similar to non-flipped approaches.

Following closely, Grover et al. (2015) publication in "Computer Science Education" has accrued a total of 235 citations (see Table 4), averaging 23.50 citations per year. This paper's substantial influence highlights the interdisciplinary appeal of flipped classroom methodologies, extending into computer science education, suggesting a broad scope of application and interest. Flipped classroom is an application of computer-assisted instruction. Students are asked to consume instructional content such as videos, online lecture, or an interactive simulation before class using computers supported either in physical locations or on campus, or they can be provided with access by computers equipped with learning material. This method advocates that teachers create a learning plan that students can explore and understand at their own pace and allow more teaching time for collaborative and competitive activities by teachers. Furthermore, computers also support cooperation; reward students with immediate feedback during classes; provide links to various other sources of material on the internet. The flipped learning model uses computers to help teachers engage students in learning and learning activities.

Additionally, despite the absence of Bhagat et al. (2016) article in "Educational Technology and Society" has gathered 174 citations, averaging 19.33 citations per year, which indicates its significant impact on discussions surrounding educational technologies. The research findings have been widely cited due to its compelling content, which compares flipped classroom learning with traditional classroom methods. The results indicate that students in flipped classrooms outperform those in traditional classrooms in terms of learning outcomes.

Other notable contributions include works by Brahimi and Sarirete (2015) whose papers continue to receive attention, reflecting ongoing interest and their contributions to understanding and enhancing the flipped classroom model. This study explores how MOOCs can be used in high school. This research delves into the applications of MOOCs, in high school settings. The integration of Massive Open Online Courses (MOOCs) is closely associated with the flipped classroom model. In a flipped classroom setup students engage with materials outside of class hours such as lectures or tutorials often delivered through online platforms like MOOCs. This approach allows students to progress through their learning at their speed while having access to a range of tools. Class time is then devoted to tasks, discussions and problem solving activities with the teacher taking on a facilitator role, than traditional lecturing.

Papers by Lo et al. (2018) also show respectable citation counts and averages per year, illustrating that their research is both referenced and valued within the academic

community. These studies provide valuable insights into effective educational practices and technology integration that are vital for enhancing learning environments.

3.1.6. Word Cloud

The provided data on keyword occurrences in research on flipped classrooms in K-12 mathematics education offers valuable insights into the primary themes and concepts being explored within this field. The term "flipped classroom" leads with 35 occurrences, affirming its central role and significance in the current educational research landscape (see Figure 8). Additionally, variations of this term, such as "flipped learning" and "flipped classroom model," also appear in the data, indicating that researchers are examining different aspects and implementations of this educational strategy.

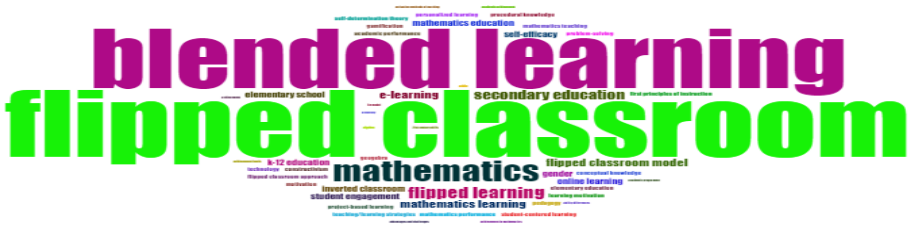

Figure 8. Word cloud

"Blended learning" is another prominent term, recorded 31 times, which highlights its strong association with flipped classroom methodologies (see Figure 8). This suggests that significant attention is being given to how blended learning approaches can be integrated with flipped classroom strategies to potentially enhance educational outcomes. The specific mention of "mathematics" and "mathematics learning," appearing a combined 15 times, underscores the focus on applying these teaching methods within mathematics education, suggesting their perceived effectiveness in improving mathematical skills and comprehension at the K-12 level. The analysis also reveals that these educational strategies are being tailored to various developmental stages, as indicated by mentions of "secondary education" and "elementary school." This suggests a nuanced approach to applying flipped classroom techniques, adapted to suit different age groups and educational needs. Moreover, the inclusion of "e-learning" points to the significant role of digital technologies in facilitating these modern educational approaches, emphasizing the integration of online and digital tools in flipped and blended learning environments.

3.2. Discussion

In the industrial revolution 4.0, technology-based learning models have increasingly mushroomed, especially with the emergence of COVID-19, learning is carried out online learning as well as blended learning, therefore students are required to have learning independence when learning online. One of the existing blended learning models is the Flipped Classroom model. This model reverses traditional learning, usually students study the material at school and then do assignments at home, but in Flipped Classroom students are asked to study the material at home and then do assignments and reinforcement at school. The traditional flipped classroom divides activities into 3 main activities, namely before class, during class and after class (Bergmann & Sams, 2012). Where during before class students study material independently at home through various learning platforms, this is in accordance with the constructivist view, where individuals actively build their own knowledge through experience and reflection on experience (Hudson & Whisler, 2008).

Based on the research results described previously, the research trend regarding flipped classrooms in K-12 shows that every year the research trend for flipped classrooms, especially in mathematics subjects, has increased, where the most documents were obtained in 2023, namely 20 documents. This is likely to continue to increase in the years to come because the use of the Flipped Classroom has a positive impact on mathematics learning outcomes (Azizah et al., 2022; Ramadoni & Chien, 2023; Supra et al., 2021)

Where the most cited articles are Lai and Hwang (2016) with the title A self-regulated flipped classroom approach to improving students' learning performance in a mathematics course. This article is the most quoted because it is closely related to student learning independence. The flipped classroom model can influence student learning independence because students are responsible for studying the material independently before entering class. This encourages students to take the initiative in understanding the material and looking for relevant learning resources outside the classroom, besides that learning with e-learning can provide positive interactions between students and teachers online (Garrison & Vaughan, 2008; Zhang et al., 2004).

The co-occurrence network analysis of author keywords from research on flipped classrooms in K-12 mathematics education provides a structured overview of how various educational concepts are interconnected, emphasizing their relevance and centrality within the academic discourse. This analysis identifies pivotal nodes and clusters that represent core areas of focus and interest in the field (see Figure 9).

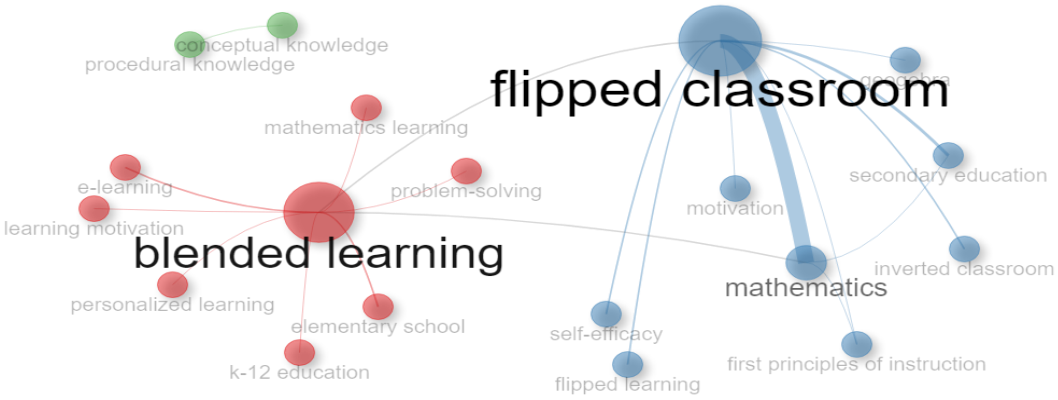

Figure 9. Network map

"Cluster 1" predominantly centers around themes of digital and blended learning environments. Within this cluster, "Blended Learning" emerges as a critical node, evidenced by its high betweenness of 84 and a PageRank of 0.192, signifying its central role in linking diverse educational concepts. This indicates that discussions around blended learning are fundamental to understanding the integration of technology in educational settings. Other keywords in this cluster, such as "e-learning", "mathematics learning", "elementary school", "k-12 education", "learning motivation", "personalized learning", and "problem-solving", exhibit lower betweenness and closeness scores. These metrics suggest that while these topics are relevant, they do not serve as central hubs like blended learning but rather as supplementary areas of interest within the network.

"Cluster 2" focuses more on specific classroom methodologies and educational levels. The keyword "Flipped Classroom" is notable for its substantial betweenness of 75 and the highest PageRank of 0.223 in this cluster, highlighting its significance and centrality in discussions related to innovative classroom methodologies. The keyword "Mathematics" also displays a notable presence with some betweenness and a moderate PageRank,

underlining its importance as a key subject within the flipped classroom discourse. Other terms in this cluster, including “flipped learning”, “secondary education”, “inverted classroom”, “self-efficacy”, “first principles of instruction”, “GeoGebra”, and “motivation”, are identified as more specific topics that, while less central, are integral to the nuanced discussions within this educational framework.

“Cluster 3” is distinguished by a focus on the types of knowledge being addressed—”Conceptual Knowledge” and “Procedural Knowledge”—both showing high closeness scores, indicating their accessibility within the cluster. However, their lower PageRank scores compared to the major nodes in other clusters suggest they are specialized discussions within the broader context of educational methods.

This analysis underscores that “blended learning” and “flipped classroom” are foundational to current discussions on educational methodologies, serving as key hubs that link various other educational concepts. When reporting these findings, it is crucial to emphasize how these methodologies are integral to the ongoing discourse on enhancing educational practices through technology integration and pedagogical innovation. Additionally, the exploration of less central but pertinent topics like “mathematics”, “conceptual knowledge”, and “procedural knowledge” points to potential areas for further focused research, aiming to deepen the understanding of their specific roles and impacts within the broader educational landscape.

4. CONCLUSION

This bibliometric study has shown research trends in the implementation of flipped classroom in mathematics learning for K-12 students in the last two decades. The research found 102 relevant articles during this period, showcasing an increase in research findings related to this subject matter from year to year. The most relevant author was Hew Khe Foon. The most cited article was Lai and Hwang’s article entitled "A self-regulated flipped classroom approach to improving students' learning performance in a mathematics course" (Lai & Hwang, 2016). Indonesia emerged as the leading country that produced articles related to this theme, with a remarkable count of 43 articles. Apart from that, the Indonesian Education University was the most productive affiliate related to this theme. Furthermore, the journal "Educational Technology and Society" was found to be the most prolific journal for publishing research outcomes.

Over the last two decades, the flipped classroom in mathematics learning has shown a close relation to blended learning. Blended learning served as a keyword that connected other learning variables, such as problem solving, self-efficacy, learning motivation, and K-12 education. New themes found in flipped classroom research were conceptual knowledge and procedural knowledge. Future researchers could use the research focus to determine the research theme. Further research could also make use the novelty that has been discussed in this research.

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