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Explaining the digital transformation of mathematics learning through the flipped classroom: A prisma bibliometric review

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***Abstract*:**
This study aims to systematically examine publication trends, implementation methods, pedagogical approaches, impacts, target education levels, and the role of digital technology in the application of the flipped classroom model in mathematics learning. The method used is the Systematic Literature Review (SLR) based on PRISMA guidelines, with additional bibliometric analysis using VOSviewer to map the relationship and development of keywords in the literature published between 2023 and 2025. The analysis of 16 selected articles indicates a growing research trend, marked by a shift from conceptual investigations toward studies emphasizing impact and student learning experiences. The results show that digital transformation in mathematics learning is reflected through the integration of digital instructional videos, LMS platforms, and online learning resources that restructure learning from a teacher-centered approach to a technology-supported, student-centered model. The findings also indicate a shift in research focus from conceptual discussions toward practical implementation and learner outcomes. The flipped classroom is implemented through a combination of pre-class digital preparation and in-class interactive activities that promote autonomy, engagement, and 21st-century skills. Despite variations in context, many of the identified challenges, such as limited digital competence and low pre-class engagement, remain relevant to Indonesian students. Overall, the study successfully addresses its objectives and provides insights that can serve as a reference for developing contextual, technology-driven mathematics learning strategies.

Keywords: Bibliometrics; Educational Technology; *Flipped Classroom*; Mathematics Learning; Prisma.

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Introduction

Innovative approaches have the potential to transform the way mathematics is taught, encouraging teachers to embrace fresh ideas and explore new teaching experiences (Cevikbas, 2020). Without limiting the use of learning media, emphasizing

the sequence of learning using individual learning spaces for direct instruction (pre-class) and the resulting group learning spaces for interactive activities involving the application of knowledge (*in class*)(Lo, 2021). The use of online learning resources for mathematics education via internet-enabled mobile devices has gained widespread popularity (Yuliana, 2024). This situation assumes the opportunity to apply the flipped classroom model to demonstrate and verify how technology plays a role in this pedagogical approach to improve learning (Moreno & Morant, 2023).

A growing number of students are losing interest in school subjects, particularly mathematics, which raises serious concerns because low engagement negatively affects both mathematical achievement and overall academic performance (Cevikbas & Kaiser, 2022). Many students also remain passive, rely heavily on teacher-centered instruction, and struggle to apply mathematical concepts to real-life situations (Albar, 2025). Despite the increasing availability of digital resources, field observations show that the digital transformation of mathematics learning has not yet been implemented effectively. It is largely due to limited teacher digital competence, insufficient technological infrastructure, and low student participation in pre-class independent learning activities. Addressing these challenges requires an instructional approach that supports active learning, fosters student autonomy, and leverages digital technology meaningfully. In this regard, the flipped classroom model emerges as a promising pedagogical alternative. By using digital technologies to deliver instructional content before class and orienting face-to-face sessions toward interaction, problem-solving, and conceptual reinforcement, the flipped classroom offers a structured pathway for advancing a more effective and meaningful digital transformation in mathematics education (Karimah, 2019; Ding, 2024).

The flipped classroom has become one of the most popular learning models, especially in mathematics (Hukom, 2025). Flipping is a blended learning strategy that involves assigning learning tasks to students at home (potentially in small groups), followed by in-class sessions focused on discussions, feedback, interaction, and performance assessments (Gonzales & Gonzales, 2024). The primary objective of the flipped classroom is to redefine the teacher's role, moving away from a traditional instructional and demonstrative approach toward a more facilitative role that emphasizes guiding and supporting students throughout their learning process (Sarwar, 2024). Since flipped classrooms allocate class time to active learning, they have demonstrated improved student performance compared to conventional teaching methods (Strelan et al., 2020; Wirth, 2024).

To create a learning environment that emphasizes meaningful student engagement, accommodates diverse learning paces, and addresses individual strengths and weaknesses, a shift in teaching approach is recommended through the adoption of the Flipped Classroom methodology (Rincón et al., 2025). The modified Flipped Classroom approach moves the theoretical component of the learning process to be completed independently outside the classroom (Bedebayeva et al., 2025). The Flipped Classroom (FC) model reflects this shift by inverting conventional teaching methods: students independently explore new content through videos and readings outside the classroom, while completing online tasks assigned by the teacher (Omoniyi, 2025). Math teachers can prepare video lessons on math content and send them to students via platforms such as WhatsApp, YouTube, and others (Annajmi & Dedi Kuswandi, 2024). The flipped classroom approach in mathematics learning and teaching is one way to

support students in actively engaging with mathematics and thereby develop mathematical competence (Creek, 2024).

The effective implementation of flipped classrooms relies on a basic level of digital teaching competence, which is essential for their proper execution and can be influenced by factors such as age, gender, experience level, and ongoing professional development (Cebi & Reisoglu, 2020; Estévez-Méndez et al., 2024). Math teachers can prepare video lessons on math content and send them to students via platforms such as WhatsApp, YouTube, and others (Annajmi & Dedi Kuswandi, 2024). Some students reported difficulty adjusting their learning habits to the flipped classroom approach and finding motivation to watch the required learning videos before class activities (Nielsen, 2023). However, various studies have shown that implementing the flipped classroom model positively affects student learning outcomes (Katopo et al., 2024). Incorporating interactive visual materials within the flipped classroom approach has been shown to enhance students' understanding of mathematical concepts (Salsabila & Lu, 2024).

This study systematically analyzes publication trends, implementation methods, pedagogical strategies, impacts, target education levels, and the role of digital technology in flipped classroom–based mathematics learning. Using a PRISMA-guided SLR combined with bibliometric analysis, it offers a comprehensive overview of topic development, keyword trends, and recent research directions from 2023 to 2025. Unlike previous partial studies, this research provides an integrated thematic synthesis and identifies dominant themes, topic relationships, and research gaps through keyword network visualization. The findings are expected to contribute essential insights for developing contextual, technology-driven, 21st-century mathematics learning strategies.

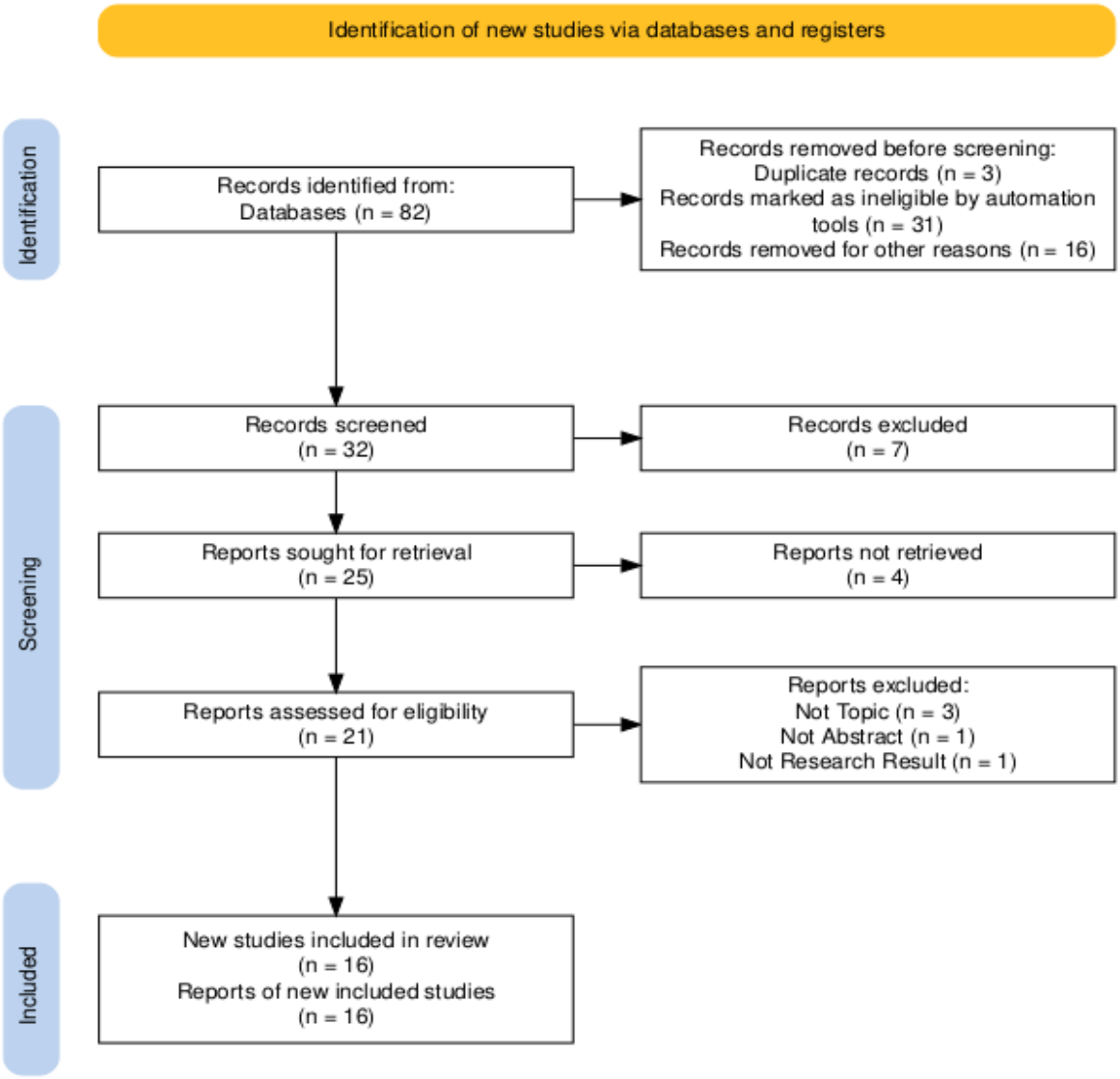
Research methods

This study employs the Systematic Literature Review (SLR) method guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, combined with bibliometric analysis, to systematically and structurally identify and assess trends in the application of the Flipped Classroom model in mathematics education. Bibliometric tools are used to enhance coding of articles, which are then categorized into broader themes aligned with the research questions (Gestiardi, 2025). His approach was selected to provide a thorough, in-depth understanding of the evolution of research, publication trends, author contributions, and key themes related to the implementation of the Flipped Classroom. The study is centered on addressing the following research questions:

RQ 1 : How have research publication trends on the Flipped Classroom model in mathematics education evolved over the past three years?
RQ 2 : What are the forms of application methods and pedagogical strategies used in implementing the Flipped Classroom model in mathematics learning?
RQ 3 : What are the primary effects of applying the Flipped Classroom approach in mathematics education?
RQ 4 : At which educational level is the Flipped Classroom model most frequently applied in mathematics learning?
RQ 5 : How do technology and digital media contribute to the effective implementation of the Flipped Classroom model in mathematics education?

The data collection process was carried out by searching a number of researcher databases using the Publish or Perish application and the help of other applications such as Zotero, Mendeley, VOSViewer, and Microsoft Excel (Watajdid et al., 2021). Eighty-two articles from Scopus were selected by searching using the title words: "Flipped Classroom" and keywords: "Mathematics". The articles found were then selected using previously determined inclusion and exclusion criteria.

The inclusion criteria for this study are as follows: (1) scientific journal articles that have been peer-reviewed and published; (2) research that specifically addresses the implementation of the Flipped Classroom model within the context of mathematics education; (3) primary research, whether quantitative, qualitative, or mixed; (4) published within 3 years between 2023 and 2025; and (5) written in English. The articles excluded from the analysis were non-scientific (e.g., opinions or editorials), studies unrelated to mathematics education, duplicates, and articles not available in full text.



Picture 1. The PRISMA Flow Diagram Summarizes The Study Selection Process

Following the PRISMA protocol, the process of selecting articles is conducted through four distinct stages, namely: (1) identification, where all articles are collected based on the initial search results; (2) screening, by removing duplication and reviewing titles and abstracts for initial screening; (3) eligibility, namely reading the full contents of the article to ensure compliance with the topic and criteria; and (4) inclusive, namely articles that are considered to meet all criteria and are included in the final analysis. This process is visualized in a PRISMA flow diagram to describe the selection stages systematically.

Articles that have met the criteria are then analyzed using a content analysis or thematic synthesis approach to identify emerging patterns of findings. Several aspects were coded during the analysis, including the year of publication, the design of the Flipped Classroom implementation, the media or technology used, research variables (such as learning outcomes, motivation, or student engagement), and the benefits and challenges encountered in its application. The outcomes of this process are presented as thematic findings that highlight trends, patterns, and research gaps relevant to advancing technology-integrated mathematics education.

Results and Discussion

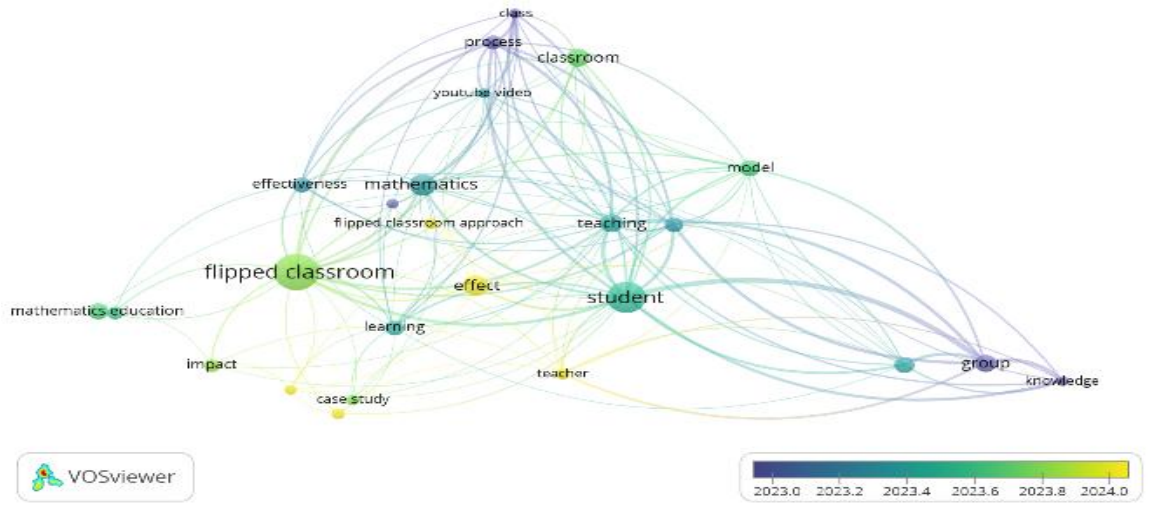
This section presents the results of 16 systematically reviewed articles on the implementation of the flipped classroom in mathematics learning. Although limited in number, the studies span various regions and educational levels (2023–2025), providing cross-context insights relevant to Indonesian students, particularly regarding digital competence, pre-class engagement, and technological access. The analysis focuses on implementation methods, technological tools, and the model's impact on learning outcomes, student engagement, and 21st-century skill development.

Table 1. Scopus Systematic Publication Results

No.	Writer	Year	Research result
1	Egorova et al. (2025)	2025	Implementing the flipped classroom strategy with audiovisual support increases student motivation and participation in mathematics learning.
2	Fitrah (2025)	2025	The implementation of PBL integrated with a flipped classroom creates an interactive learning environment, encourages active involvement, and improves students' understanding and skills in solving mathematical concepts.
3	Wang (2025)	2025	The flipped classroom model has shown positive impacts on overall mathematics education.
4	Country (2024)	2024	Students taught mathematics using the flipped classroom approach had higher achievement and interest scores in mathematics than their peers taught using the conventional approach.
5	Awi et al. (2024)	2024	Integration of the flipped classroom approach with scaffolding via an LMS significantly improved prospective mathematics teachers' geometry achievement.
6	Kadarisma et al. (2024)	2024	A self-regulated flipped classroom approach to

No.	Writer	Year	Research result
			improving student learning performance in mathematics courses
7	Fredriksen et al. (2024)	2024	The concept of combining the Flipped Classroom and Inquiry-Based Mathematics Education (IBME) seems to be paying off, as it encourages students to reflect more deeply on mathematics and offers the potential for better teacher guidance.
8	Kiem (2024)	2024	First, mathematics teacher educators must allocate sufficient time for course preparation and transition to the flipped classroom structure. In addition, the availability and proficiency in utilizing technological tools must be ensured. Second, emphasis should be placed on enhancing self-directed learning among pre-service teachers and developing interactive dynamics during out-of-class activities.
9	Ergen (2024)	2024	The flipped classroom model is more effective for mathematics achievement than the curriculum-based teaching method.
10	Cevikbas (2023)	2023	The flipped classroom is an innovative instructional approach that offers numerous advantages for enhancing the teaching and learning of mathematics.
11	Beltozar-Clemente et al. (2023)	2023	The academic performance and positive attitudes of students towards mathematics who took courses using the flipped classroom were compared with those of students who did not use this methodology.
12	Romero (2023)	2023	Applying traditional teaching methods in digital environments can negatively affect students' attitudes toward mathematics. The flipped classroom approach can help counteract this decline by supporting middle school students in maintaining their enjoyment, motivation, confidence, and academic performance in mathematics.
13	Sopamena (2023)	2023	Students achieve better learning outcomes in mathematics when taught using the flipped classroom model compared to traditional teaching methods.
14	Ruiz-Palmero (2023)	2023	The implementation of a flipped classroom in an online context improves students' academic performance in mathematics, with the use of digital resources, particularly for geometry, helping enhance various student competencies and skills.
15	Salas-Rueda (2023)	2023	The flipped classroom facilitates active student participation in the mathematics learning process, promotes the construction of new educational virtual spaces, and enhances the educational process through the integration of technological tools before, after, and during face-to-face sessions.
16	Orlić et al. (2023)	2023	The use of the flipped classroom model (FCM) has a positive impact on the quality and resilience of students' mathematical knowledge, especially for students taught to measure and quantify through FCMWFR, compared to traditional teaching.

RQ 1 : Research publication trends on the Flipped Classroom model in mathematics education have evolved over the past three years.



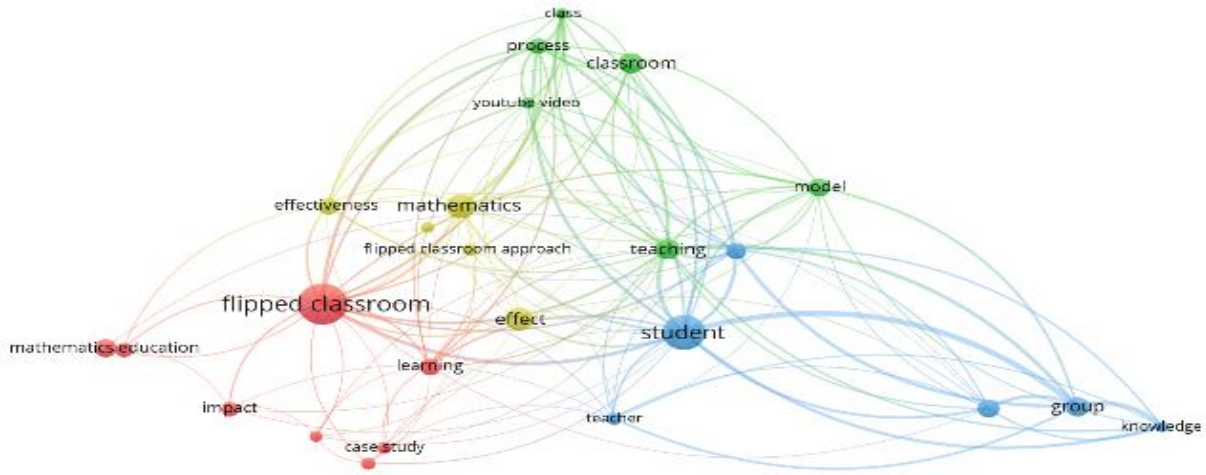
Picture 2. Overlay Visualization

A VOSviewer overlay visualization accessed in May 2025 shows that research on flipped classrooms in mathematics education has evolved dynamically over the past three years. Keywords such as 'flipped classroom' and 'students' indicate the primary research focus. In contrast, newer keywords, such as case studies, impact, effects, and teachers, highlight the recent shift toward practical, impact-oriented studies. Earlier keywords, such as models and mathematics education, reflect the conceptual focus of research in 2023. The strong connection between students, teaching, learning, and processes underscores the continued emphasis on student-centered learning, and the emergence of 'YouTube videos' signals increased attention to digital media. Overall, these patterns indicate a transition from theoretical discussions to practical, implementation-based research.

RQ 2 : Forms of application methods and pedagogical strategies used in implementing the Flipped Classroom model in mathematics learning.

Based on the SLR findings from 16 articles and bibliometric visualization maps, the implementation of the Flipped Classroom model in mathematics education exhibits a diverse range of approaches, including integration with other pedagogical methods such as Problem-Based Learning (Fitrah, 2025) and Inquiry-Based Mathematics Education (Fredriksen et al., 2024), strengthening the function of the flipped classroom in improving conceptual understanding and in-depth reflection on mathematical material. Several studies, such as those conducted by Orlić et al. (2023), even modify the model with the Flipped Classroom with Feedback and Reflection (FCMWFR) approach to improve the quality and resilience of students' mathematical knowledge, especially in the concept of measurement. Whereas Wang (2025) and Cevikbas (2023) reported that this model not only had a positive impact on understanding mathematical concepts but also formed a more reflective and independent learning pattern. It aligns with the keyword cluster in the visualization, which includes the terms flipped classroom

methodology, case study, and experience, indicating the dominance of a practical, experience-based approach. Other studies, such as Awi et al. (2024), emphasize integrating the Flipped Classroom with an LMS and scaffolding to optimize learning outcomes. Therefore, it can be concluded that the implementation of the flipped classroom model is not uniform, but rather flexible and adaptable, frequently integrated with contextual pedagogical strategies that promote learner autonomy and active student engagement.



Picture 3. Network Visualization

Based on a bibliometric visualization using VOSviewer shows increasingly diverse and interconnected approaches to flipped classroom implementation in mathematics learning. Central keywords such as 'flipped classroom,' 'student,' 'mathematics,' and 'teaching' indicate the model's dominant role, with strong links to impact, effectiveness, learning, and case study, reflecting its focus on experiential and empirically evaluated learning outcomes. The connections between 'student' and 'teacher' emphasize a student-centered approach, while clusters involving 'student', 'group', and 'knowledge' highlight collaborative learning and conceptual development. Another cluster related to model, classroom, and process shows structured implementation supported by digital media, including YouTube videos. Overall, these patterns indicate a shift from theoretical evaluations to more complex, collaborative, and technology-oriented pedagogical applications of the flipped classroom over the past three years. The focus of research has shifted from simply testing the model to developing contextual, student-centered active learning strategies in the digital era. Meanwhile, Kadarisma et al. (2024) explore the effectiveness of self-paced learning arrangements through flipped classrooms, resulting in improved learning performance in mathematics courses.

RQ 3 : The primary effects of applying the Flipped Classroom approach in mathematics education.

The analysis of the SLR documents reveals that implementing the Flipped Classroom model yields a range of positive effects in the context of mathematics education. Most articles, such as those by (Country, 2024; Ergene, 2024; Sopamena, 2023), concluded that this model had a significant positive impact on students' learning

motivation, academic performance, and participation. This approach was selected due to its ability to shift students' roles from passive recipients to active participants, thereby enhancing both their engagement and learning outcomes. Research by Egorova et al. (2025) and Romero (2023) confirmed that the use of audiovisual media and flipped learning structures can increase students' motivation, self-confidence, and enthusiasm for mathematics. Thematically, these studies reveal the positive impact of the Flipped Classroom model on three main aspects: 1) learning outcomes and academic achievement (Country, 2024; Ergene, 2024; Sopamena, 2023), 2) active participation and involvement of students (Egorova et al., 2025; Salas-Rueda, 2023), and 3) development of 21st century skills, such as critical thinking and independent learning (Kiem, 2024**;** Ruiz-Palmero, 2023).

On the other hand, bibliometric visualization displays keywords such as self-efficacy, student perceptions, and skills, indicating that the study also highlights psychological aspects and non-cognitive skills. The implementation of flipped classrooms not only affects final grades but also students' critical thinking skills, collaboration, and self-confidence in completing math assignments independently. The flipped classroom model shows positive impacts on overall mathematics education (Wang, 2025). It shows that the trend toward implementing flipped classrooms is not only technical but also strategic in improving the overall quality of mathematics learning. However, several studies also highlight implementation challenges, such as teacher readiness in designing digital materials, time constraints, and the need for strong technological literacy, as noted by Kiem (2024). Therefore, the success of implementing flipped classrooms depends heavily on infrastructure readiness, teacher competence, and the flexibility of the curriculum to adapt to this pedagogical innovation.

RQ 4 : At the educational level, the Flipped Classroom model is most often applied in mathematics learning.

Table 2. Thematic Study of Flipped Classroom in Mathematics Learning

Writer	Year	Educational level	Media / Platform	Main Impact	Special Approach
Egorova et al.	2025	Secondary school	Audiovisual	Increase student motivation & participation	-
Nature	2025	Secondary school	Not mentioned	Interactive, increased understanding of concepts	Integrated with PBL
Money	2025	General	Not mentioned	Overall effectiveness in mathematics learning	-
Country	2024	Secondary school	Not mentioned	Student achievement & interest increases	-
Awi et al.	2024	Prospective Teacher (College)	LMS	Improving geometry achievement	Scaffolding support
Kadarisma et al.	2024	College	-	Improve learning performance	Self-regulated
Fredriksen et al.	2024	Secondary school	-	Deep reflection & teacher guidance	Integrated with IBME

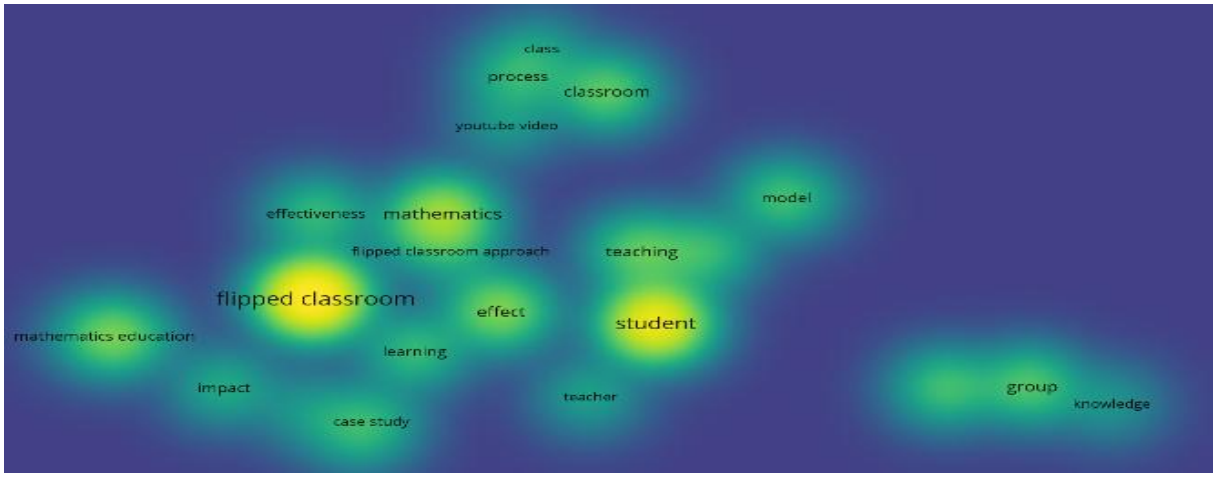
Writer	Year	Educational level	Media / Platform	Main Impact	Special Approach
Kiem	2024	Prospective teacher	-	Technical challenges & self-paced learning development	Teacher preparation & technology
Ergen	2024	Secondary school	-	Higher mathematics achievement	Compared to the conventiona l curriculum
Cevikbas	2023	General	-	There are many pedagogical benefits in learning mathematics.	-
Beltozar-Clemente et al.	2023	Secondary school	-	Students' academic performance & positive attitudes improved.	-
Romero	2023	Secondary school	-	Maintaining motivation, attitude & math values	Responding to passive digital space
Sopamena	2023	Secondary school	-	More effective than traditional models	-
Ruiz Palmero	2023	High School (Online)	Digital resources	Improve competence & skills	Online context
Salas Rueda	2023	General	Digital technology	Promoting virtual spaces & active learning	Digital learning space innovation
Orlic et al.	2023	Secondary school	-	Knowledge quality & resilience increase	FCMWFR Model

Based on the SLR findings from the analysis of 16 articles, the implementation of the Flipped Classroom model is primarily concentrated at the secondary school and higher education levels, particularly in the training of prospective mathematics teachers. Articles such as (Country, 2024; Ergene, 2024; Sopamena, 2023) examined the effectiveness of this model at the secondary school level, while a study by Awi et al. (2024) and Kiem (2024) highlights its application to mathematics education students. Bibliometric visualization supports this finding by revealing keywords such as 'higher basic education students,' indicating that the target of flipped classroom implementation tends to be students who already have a foundation for independent learning. The focus at this level is on students' cognitive readiness to access materials before class and on the method's effectiveness in supporting active engagement in complex mathematics learning.

RQ 5 : Digital technology and media contribute to the effective implementation of the Flipped Classroom model in mathematics education

Regarding the use of technology, almost all studies emphasize the importance of digital media as a key element in implementing this model. Although not all studies explicitly mention the media used, the majority underscore the importance of using technology to deliver content and stimulate student interaction in the classroom. For

example, Beltozar-Clemente et al. (2023) noted that the use of flipped classrooms increased students' positive attitudes towards mathematics, partly due to easy digital access to learning materials. Starting from learning videos, LMS platforms, to interactive virtual spaces, as explained by Salas-Rueda (2023), which shows that flipped classrooms are able to facilitate new collaborative educational spaces, both before, during, and after face-to-face sessions. Technology and digital media serve as key components in ensuring the effective implementation of the Flipped Classroom model, as seen in the findings of Ruiz-Palmero's (2023) article, Salas Rueda (2023), and Awi et al. (2024), which emphasize the use of LMS, learning videos, and online resources as the core of the pre-class phase. It is reinforced by bibliometric visualizations that highlight keywords such as ICT environment, education technology, and digital resources. Digital media allows students to learn flexibly and at their own pace, while face-to-face time is used for problem-solving and discussion. In addition, the readiness of digital infrastructure and teacher technological literacy are important factors that influence the effectiveness of this model, as emphasized in the study Kiem, (2024). Thus, Flipped Classroom is not only a pedagogical model, but also relies heavily on an educational technology ecosystem that supports active and independent learning.



Picture 4. Density Visualization

The image is a density map visualization of bibliometric analysis using VOSviewer that illustrates the frequency density of keyword occurrences in research related to Flipped Classroom in mathematics learning. The area marked in yellow shows the most frequently occurring keywords and is the main focus in the literature, namely the flipped classroom, students, and mathematics. The green color indicates medium frequency, while the blue area shows keywords that rarely appear. From this map, it can be concluded that the most dominant research focus is on the implementation of the Flipped Classroom model, student engagement, and its effectiveness and impact in mathematics learning. Other supporting keywords, such as teaching, effect, learning, and classroom, also appear quite often, indicating a pedagogical approach that emphasizes the role of teachers, the learning process, and evaluation of results. On the other hand, keywords such as case study, group, knowledge, and teacher appear with lower intensity, indicating that these aspects have not been explored in depth. Therefore, this

visualization not only identifies popular topics but also provides directions for further exploration of areas that are still rarely researched.

The findings of this review suggest that the Flipped Classroom model is an adaptive and progressive learning approach for mathematics education. The growing trend shows a paradigm shift from traditional teaching to more interactive, reflective, and technology-based learning. This study can serve as an important reference for educators, researchers, and policymakers in developing more effective, contextually grounded, 21st-century mathematics learning strategies. It aligns with previous studies suggesting that flipped learning pedagogy can positively influence behavioral, cognitive, and emotional engagement, as it offers numerous opportunities for students to engage with and learn mathematics (Cevikbas, 2022). Prospective mathematics teachers demonstrate improved problem-solving abilities and enhanced creative thinking when engaged in Android module-based inquiry in a flipped classroom. This approach effectively extends learning time, facilitates greater knowledge acquisition, and fosters shared responsibility for learning, promoting a deeper learning experience (Ariani, 2022).

Additionally, the flipped classroom method has been shown to enhance various dimensions of student engagement, including behavioral engagement (e.g., interaction and active participation), emotional engagement (e.g., satisfaction with the course), and cognitive engagement (e.g., understanding of mathematical concepts) (Lo, 2021). Student engagement with RME (Realistic Mathematics Education) tasks requires a longer duration than what is typically available in a single flipped classroom session, which usually includes one out-of-class and one in-class component (Fredriksen, 2021). An effective flipped classroom—one that consistently yields better academic outcomes than traditional methods—relies on structured discussions, teacher feedback, and peer collaboration, forming a solid framework for mathematics instruction (Fung, 2021). Therefore, both individual and comprehensive studies conclude that the flipped classroom model can enhance the quality of mathematics education by increasing student engagement, promoting active participation, and allowing classroom time to be devoted to deeper problem-solving and conceptual understanding. These positive effects, however, depend on careful, contextually aligned implementation.

Conclusion and Suggestions

A PRISMA-guided systematic review and bibliometric analysis of 16 studies from 2023 to 2025 shows an increase in attention to flipped classroom research in mathematics education, with a shift from conceptual discussions to empirical evaluations of learning impacts. Implementation generally combines pre-class digital preparation with in-class problem-solving activities and yields improvements in learning outcomes, motivation, participation, and 21st-century skills. Most studies focus on secondary and higher education and emphasize the essential role of digital technologies in enabling flexible learning. Future research is recommended to explore applications in primary education, assess long-term effects, and examine digital readiness issues to broaden the model's applicability.

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