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FLIPPED CLASSROOM IN MATHEMATICS EDUCATION AFTER PANDEMIC: A SYSTEMATIC LITERATURE REVIEW

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Abstract

The COVID-19 pandemic has highlighted the need for adaptive learning models, especially in mathematics education. This study aims to analyze publications on the Flipped Classroom model in post-pandemic mathematics education (2021–May 2023) and to explore its future development. The method used is a systematic literature review of 10 articles, consisting of two Scopus-indexed articles and eight articles from Google Scholar obtained using the Publish or Perish application. The total number of participants involved in the reviewed studies is 1,200, comprising 370 elementary school students, 208 junior high school students, 179 senior high school students, and 417 university students. The findings indicate that the digital-based *Flipped Classroom* model can enhance mathematical communication skills, critical thinking, conceptual understanding, problem-solving abilities, and higher-order thinking. Moreover, it positively influences students' self-confidence, creates a more interactive classroom environment, generates positive learning responses, and supports social interaction in online settings. These results suggest that the *Flipped Classroom* is an effective instructional model and is recommended for mathematics learning in the post-pandemic era.
Keywords: *flipped classroom; mathematics education; systematic literature review*

Abstrak

Pandemi COVID-19 mendorong perlunya model pembelajaran yang adaptif, termasuk dalam pendidikan matematika. Penelitian ini bertujuan menganalisis publikasi mengenai model *Flipped Classroom* dalam pendidikan matematika pascapandemi (2021–Mei 2023) dan menggambarkan arah perkembangannya. Metode yang digunakan adalah *systematic literature review* terhadap 10 artikel, terdiri dari dua artikel terindeks Scopus dan delapan artikel dari Google Scholar yang diperoleh menggunakan aplikasi Publish or Perish. Total peserta dalam studi ini berjumlah 1.200, terdiri atas 370 siswa SD, 208 siswa SMP, 179 siswa SMA, dan 417 mahasiswa. Hasil kajian menunjukkan bahwa model *Flipped Classroom* berbasis digital dapat meningkatkan kemampuan komunikasi matematis, berpikir kritis, pemahaman konsep, pemecahan masalah, dan berpikir tingkat tinggi. Selain itu, model ini berpengaruh positif terhadap kepercayaan diri siswa, suasana kelas yang lebih interaktif, respons yang baik terhadap pembelajaran, serta mendukung sosialisasi di lingkungan daring. Temuan ini menunjukkan bahwa *Flipped Classroom* merupakan model pembelajaran yang efektif dan dapat direkomendasikan untuk pembelajaran matematika setelah pandemi.
Kata kunci: *flipped classroom*; pendidikan matematika; systematic literature review

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INTRODUCTION

One of the impacts of the COVID-19 pandemic on the education sector is in teaching and learning activities (Nugraheni et al., 2022) turning into emergency distance learning (Assidiqi & Sumarni, 2020; Vahle et al., 2023). Educational institutions must have innovations (Yamin & Syahrir, 2020) that can provide solutions and prevent Covid-19 (Rahmi, 2020). Education must continue to be carried out efficiently, both online and blended knowledge, while keeping students active and having positive behavior (Sugiharti et al., 2022) from their respective homes by using information and communication technology devices (Aznam et al., 2021; Jiménez et al., 2021). Technology as an action platform for new literacy and shared learning (Guanabara et al., 2011; Tchoshanov, 2013). The use of technology has shown increased performance, motivation, and problem-solving (Rodríguez-Jiménez et al., 2023) and has been overgrown in recent decades (Jiménez et al., 2021).

However, learning in Indonesia is not optimal because the signal is often not excellent and unstable enough (Ahmadi & Syahrani, 2022; Nurmawati et al., 2022). One learning model that depends on technology (Divjak et al., 2022) and can be a solution is the Flipped Classroom (FC) (Nurhayati, 2022). The FC model is more effective than the traditional learning model (Zeitoun et al., 2023) in the moderate category (Sopamena et al., 2023), can increase student motivation (Amalia et al., 2023), and has proven to be very effective in banning almost all subjects (Atta & Bonyah, 2022). The digital era requires teachers to master cyber skills and basic technology (Ibda et al., 2023).

FC model is a traditional learning model that is in reverse; namely, the classroom now conducts learning that usually does occur outside and learning that is in the classroom is done outside the classroom (Låg & Sæle, 2019), by relying on technology (Divjak et al., 2022). The FC model is a learning model that provides videos before class starts as an alternative to traditional learning (Lewis, 2019; Vanka et al., 2020) and emphasizes adequate time in class (Köksal & Han, 2022). Students obtain material educators provide through digital education through video or outside the classroom (Allison, 2021; Syajili & Abadi, 2021). Students can study the material without being bound by time, whenever and wherever they keep repeating it. In learning using the FC model, the introduction is 5 minutes, question and answer time on video is 10 minutes, and then exercises and laboratory activities are guided and independent (75 minutes) (Bergmann & Sams, 2012). During meetings with educators, all that remains is to discuss poorly understood material (Affida & Zainiyati, 2022) by providing more individual and targeted support to students, answering questions, facilitating discussions, and helping students overcome problems (Tunggyshbay et al., 2023).

The FC framework improves the quality of learning in the classroom (Fredriksen, 2021). The flipped classroom has many benefits, especially for teachers, administrators, parents, and students. During the COVID-19 pandemic, using FC could improve students' understanding of concepts and self-efficacy (Syajili & Abadi, 2021). This model also positively impacts blind students during the Covid 19 pandemic by repeating learning videos until they know they are not limited by time (Nordin et al., 2023). Educators and researchers agree that FC frees up class hours for social interaction, collaboration, investigation, and deep learning, so it has a high potential to improve the quality of teaching and learning (Cevikbas & Kaiser, 2023).

After the COVID-19 pandemic, the learning process continues as before. However, how has the implementation of post-pandemic FC, especially in mathematics education, bearing in mind the influence of this model during the COVID-19 pandemic, had a significant effect? Therefore, researchers are interested in reviewing the implementation of the Flipped Classroom model in mathematics education after the COVID-19 pandemic..

METHOD

This research method was a systematic literature review descriptive regarding the Flipped Classroom model in mathematics education after the pandemic. This study employs the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model to organize and report the results of a systematic literature review. Marifah (ref Syari & Meiliasari, 2024) said that the role of the PRISMA Protocol is the process of assessing and selecting all empirical that are by the evidence and will be used to answer research questions. The study selection process follows the PRISMA stages, including identification, screening, eligibility assessment, and inclusion of relevant studies. A PRISMA flow diagram is used to illustrate the study selection process. The results of the literature review are reported according to the items recommended by PRISMA, including study characteristics, main findings, and quality assessment.

The database uses Scopus and Google Scholar with the help of Publish or Perish and keywords (("flipped classroom") AND ("mathematics education")). Then, the criteria for the articles used are applied; articles must be open access, namely published in English, published from 2021-May 2023, only journal articles included (excluding review), and the others did not. The papers were determined and analyzed from both databases.

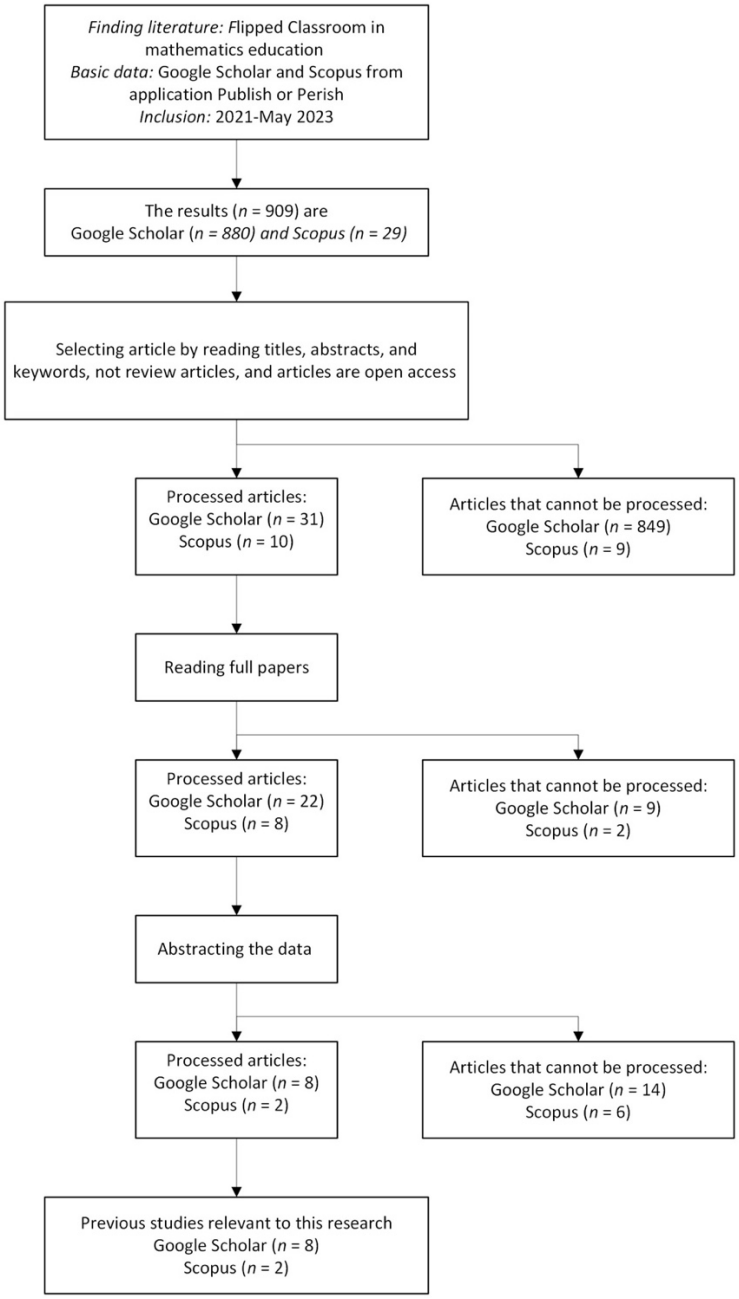

Figure 1. Systematic Review Procedure

The following took the following steps:

1. Data from 880 Google Scholar articles and 29 Scopus articles on flipped classroom in mathematics education derived from the Publish or Perish application were collected.
2. Select articles based on abstracts, keywords, not-reviewed articles, and open-access articles, then continue by downloading the article. Based on this process, 31 articles from Google Scholar and Scopus were obtained, as well as 10 articles originating from Publish or Perish.
3. Read full papers that match the research objectives, discarding excluded articles to obtain 22 suitable articles on Google Scholar and 8 Scopus articles from Publish or Perish.

4. Abstract the data in the article by selecting data following the research objectives to obtain ten articles relevant to the research objectives. The article consists of 8 Google Scholar articles and 2 articles from Scopus.
5. Present data analysis using descriptions and presented using tables.
   a. Identification article

      Inclusion and exclusion criteria are presented in Table 1 below.

Table 1. Criteria Inclusion and Exclusion

Include	Exclusion
Research articles (quantitative, qualitative, mixed)	Learning materials outside mathematics (science, language, etc.)
Published 2021- May 2023	Article published before 2021 and after May 2023
Focuses on the application of the Flipped Classroom model in mathematics learning	It does not focus on the Flipped Classroom model
Participants are elementary to pre-service teacher	Participants are teacher
English language publications	Publications in languages other than English
Scientific journal (excluding proceedings, theses, dissertations, and reviews)	Not a scientific journal article (example: editorial, opinion piece, book chapter)
Open access	Close access

Articles published in English, such as the Flipped Classroom model in mathematics education, were published after the pandemic from 2021 to May 2023. The databases used are Scopus and Google Scholar with the help of Publish or Perish and the keywords ("flipped classroom") AND ("mathematics education"). The data obtained were 909, based on inclusions and exclusions; they screened to obtain ten articles. Researchers excluded articles other than mathematics education (biology, physics, mathematical psychology, mathematical engineering), other than the flipped classroom (flipped learning, flipped classroom pedagogy, flipped classroom learning), and English language. The articles are subsequently analyzed. The data collected included article titles and author names, journal names, year of publication, research objectives, methods, instruments, participants, study locations, technology, variables, topics, and research results.

The article uses descriptive qualitative, quasi-experimental, qualitative case study, experiment, Plomp development, mixed methods, and quantitative methods. The instruments used in the report are tests, observations, questionnaires, interviews, group discussion forums, and documentation. These diverse methodologies and instruments ensure a comprehensive analysis of the research subject.

   b. Analysis procedure

      This study shows the current state of the literature and describes how it will be in the future. The aspects presented are the type and author of the research (location, year of

publication, journal), methods, and research results. Next, the researcher explains how to implement FC in post-pandemic mathematics education and its future picture.

RESULTS AND DISCUSSION

Determining what, by whom, where, how, when, and what founded the goal of a systematic review (Aznam et al., 2022) so that the authors can determine the implications of FC in post-pandemic mathematics education and help plan future research. They have presented 11 post-pandemic research articles from 2021-May 2023 concerning Flipped classrooms in mathematics education after the pandemic in Table 2. The participants totaled 1,200, consisting of 370 elementary school students, 208 junior high school students, 179 high school students, and 417 university students.

Table 2. Scientific work on Flipped Classroom in mathematics education

No	Author (year)	Participant	Study location
1	Jeong, et al (Jeong & González-Gómez, 2022)	274 pre-service teachers	Spain
2	Jeong, et al (Jeong & González-Gómez, 2021)	143 pre-service teachers	Spain
3	Putri, et al (Putri et al., 2023)	Six students in junior high school	Indonesia
4	Sani, et al (Aneshie-Oktapa et al., 2021)	54 students in senior high school	Nigeria
5	Romero & Angeles (Romero & Angeles, 2021)	20 students in junior high school	Philippine
6	Sugiharti, et al (Sugiharti et al., 2022)	370-student elementary school	Indonesia
7	Rohmatulloh (Rohmatulloh et al., 2022)	112 students in junior high school	Indonesia
8	Batlolona (Palinussa et al., 2021)	36 students in senior high school	Indonesia
9	Pardimin (Pardimin et al., 2022)	70 students in junior high school	Indonesia
10	Atta & Brantuo (Atta & Brantuo, 2021)	50-student senior high school	Ghana

Geographic scope

The study was conducted in five countries, namely Indonesia (50%), Spain (20%), Nigeria (10%), Ghana (10%), and the Philippines (10%). Only one article was a development paper (10%), and the rest was research (90%). A total of 26 writers from five countries, 15.38% of writers from Indonesia, studied learning development and presented the rest of the research in Table 3. Many Indonesians who researched the subject according to keywords show that Indonesia has increased consumption of digital content (Aznam et al., 2022) in mathematics education.

Table 3. Study location and author (based on author affiliation) Flipped Classroom in Mathematics education after a pandemic

	Study location		Authors	
Country	N	%	N	%
Indonesia	5	50	17	65,39
Spain	2	20	2	7,69
Nigeria	1	10	3	11,54
Ghana	1	10	2	7,69
Philippine	1	10	2	7,69
Total	10	100	26	100

Scope by field and research method

Several Flipped classroom studies in mathematics education after the pandemic have been conducted in 10 journals, using various learning methods and technology. Leedy & Ormrod (ref Williams, 2007) said that a research methodology is a general research approach researchers use.

Table 4. Journal distribution, research method, and technology used in an article on Flipped Classroom in mathematics education after a pandemic

Journal Name	Method	Technology	No. of paper	Field total N	%
Heliyon	Experiment	Moodle, video lessons, flash simulators, written materials	1	1	10
Mathematics	Randomized experimental design	Open Calculation based on Number (OCN)	1	1	10
Mathematics education journal	Qualitative descriptive	Digital media	1	1	10
African Journal of Science, Technology & Mathematics Education (AJSTME)	Quasi-experimental research design	Video-aided instructional package	1	1	10
American Journal of Education and Practice	Quasi experimental design	digital devices, online learning applications, and social media	1	1	10
International Journal of Humanities and Social Science	Qualitative case study	Google meet	1	1	10
ICCM-Journal of Social Science and Humanity	Experimental research design	Online learning platform	1	1	10
Inovasi Matematika (Inomatika)	Pseudo experiment	Learning videos and software	1	1	10
Technology Reports of Kansai University	Plomp development	Learning videos and Edmodo	1	1	10
Journal of Positive School Psychology	Mixed method	Video YouTube, learning application	1	1	10

Table 4. shows that as much as 60% used the experimental method and published each article in a different journal.

Overall results categorized by research questions

A comprehensive review of 10 articles published between 2021 and May 2023 examines the application of the Flipped Classroom (FC) model in post-pandemic mathematics education. The findings consistently demonstrate the positive implications of the FC model on learning outcomes, student engagement, and attitudes. The implementation of the FC model in post-pandemic mathematics education has been shown to enhance learning outcomes (Sugiharti et al., 2022). Additionally, student achievement has been observed to increase (Alviar & Solon, 2023; Aneshie-Oktapa et al., 2021; Pardimin et al., 2022).

The FC model has been recognized as an effective strategy for online learning, fostering positive attributes such as increased engagement and socialization (Romero & Angeles, 2021). Furthermore, the FC model has been found to be interactive (Jeong & González-Gómez, 2022) and has garnered a higher preference among students and elicited positive responses (Jeong & González-Gómez, 2021). These results align with previous research (Cevikbas & Kaiser, 2022; Cronhjort et al., 2018), which suggests that the FC model can enhance student engagement and learning outcomes. This is attributed to the increased relaxation, motivation, confidence, activity, and responsibility among students, which leads to a sense of control over their education (Karjanto & Acelajado, 2022). Notably, some students expressed a desire to retake the FC class (Pardimin et al., 2022).

The primary findings of this study demonstrate a substantial transformation in the methodology of mathematics education through the implementation of the Flipped Classroom (FC) model. Post-pandemic, digital technology has transcended its role as a mere tool and has become an integral component of the mathematics learning process. Several key implications emerge from this transformation are digital technology facilitates personalized learning experiences, significantly extending the flexibility of learning time and space, and it enhances cognitive skills more effectively compared to traditional teaching methods.

The Flipped Classroom model has been shown to improve various aspects of mathematics education, including mathematical written communication skills (Putri et al., 2023), critical thinking skills (Aneshie-Oktapa et al., 2021), conceptual understanding (Atta & Brantuo, 2021), mathematical problem-solving abilities (Rohmatulloh et al., 2022), and higher-order thinking skills (Palinussa et al., 2021). These improvements are in alignment with the research findings of Kurniawan & Mashuri (2021). Additionally, these findings are further supported by the research conducted by Nadarajan et al. (2023), which emphasizes the effectiveness of the Flipped Classroom model in enhancing overall educational outcomes.

Factors that influence the successful implementation of the Flipped Classroom model include the utilization of digital media, such as learning videos, in the form of educational content

(Aneshie-Oktapa et al., 2021; Atta & Brantuo, 2021; Palinussa et al., 2021; Pardimin et al., 2022; Putri et al., 2023; Rohmatulloh et al., 2022; Romero & Angeles, 2021). Additionally, active student involvement in both independent study at home and classroom discussions is crucial (Aneshie-Oktapa et al., 2021; Atta & Brantuo, 2021; Pardimin et al., 2022; Putri et al., 2023; Rohmatulloh et al., 2022; Romero & Angeles, 2021). Furthermore, student attitudes, confidence, and responses to learning activities play significant roles (Jeong & González-Gómez, 2021; Pardimin et al., 2022; Romero & Angeles, 2021). Other factors that influence the success of the Flipped Classroom model include educational background, teacher management abilities, learning motivation, assessment methods, teaching materials, and student worksheets (Atta & Brantuo, 2021; Jeong & González-Gómez, 2021; Palinussa et al., 2021; Pardimin et al., 2022; Romero & Angeles, 2021). Notably, some students expressed a desire to retake the Flipped Classroom course (Pardimin et al., 2022). Despite the potential of the flipped classroom (FC) approach in mathematics education, there are several challenges that need to be addressed. Some students lack motivation and readiness to participate in learning, and there are technical difficulties, such as internet connection problems that interfere with student participation in synchronous classes (Romero & Angeles, 2021).

Cross-study comparisons have shown variations in the implementation of FC, including differences in technology platforms (videos, learning apps, simulations, and variations in the intensity of digital interactions) and adaptations to different educational contexts. However, despite the positive potential of FC, several implementation challenges exist, such as the digital divide between regions, variations in teacher technology skills, limited internet infrastructure, and different student motivations and readiness. Furthermore, based on a global perspective, the geographical analysis of the research revealed the dominance of research from Indonesia (50%), indicating the need for more global representation and comparative research between regions. Therefore, based on the synthesis of articles, it is recommended that the development of FC models be more contextualized, that more innovative pedagogical approaches be integrated, that interactive digital materials be redesigned, and that teachers' digital skills be improved.

This systematic review study has several limitations, including a limited time span (2021-May 2023), a focus on English articles, and most samples from Indonesia. Therefore, further research is recommended to explore FC on specific mathematics topics, investigate the long-term impact, develop a comprehensive assessment framework, and examine variations of FC models across different educational contexts. This research contributes significantly to understanding the post-pandemic pedagogical transformation, identifying the potential of technology in mathematics education, and providing a conceptual framework for developing innovative learning models. Flipped Classroom is not just an alternative method but a new paradigm in mathematics education that integrates digital technology fundamentally.

CONCLUSION

A key finding of this study is that the implications of the flipped classroom (FC) model for post-pandemic mathematics education continue to positively influence student learning outcomes, engagement, and attitudes, as they were prior to the pandemic. The mathematical abilities that can be enhanced by the FC model in mathematics education post-pandemic include written communication, critical thinking, conceptual understanding, problem-solving, and students' higher-order thinking skills. This article suggests that more systematic and strategic research through systematic reviews can assist researchers in gaining a better understanding of the flipped classroom in mathematics education post-pandemic. Educators continue to utilize this model because it incorporates technology and enhances student learning outcomes, engagement, and positive attitudes.

Further research can be conducted by expanding the scope of the research sample and employing a different search engine. Additionally, innovative learning strategies or teaching materials can be developed, and the effectiveness of the FC model in teaching specific mathematical topics or concepts that are perceived as challenging or complex for students can be examined. Furthermore, the FC model can be combined with other learning approaches or models and integrated with another technological platform.

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