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# The Effect of Flipped Learning Models on Students' Mathematical Abilities: A Meta-Analysis Study

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**Abstract:** The Flipped Learning Model (FLM) has become a global phenomenon over the last decade and has significantly influenced educational practices worldwide. However, previous studies have reported inconsistent findings regarding its effectiveness in mathematics learning. Consequently, educators require more reliable and comprehensive evidence concerning the impact of FLM on students' mathematical abilities. Therefore, this study aims to conduct a meta-analysis to investigate the overall effect of FLM on students' mathematical abilities and to examine the research characteristics that may influence its effectiveness. This meta-analysis analyzed 36 effect sizes derived from 25 studies published in Scopus-indexed journals between 2014 and 2024. Comprehensive Meta-Analysis (CMA) software was employed to analyze the data. The findings revealed a pooled effect size of 1.35, indicating a very large positive effect of FLM on students' mathematical abilities. Furthermore, the moderator analysis showed that the effectiveness of FLM varies according to educational level, type of FLM, experimental class capacity, platform type, and type of mathematical ability. These findings suggest that FLM can serve as an effective instructional approach for enhancing students' mathematical abilities when implemented under appropriate learning conditions.

**Keywords**: Effect size; Flipped learning model; Mathematical abilities; Meta-analysis; Scopus data base.

**Abstrak:** Model *Flipped Learning* (FLM) telah menjadi fenomena global selama satu dekade terakhir dan memberikan pengaruh yang signifikan terhadap praktik pendidikan di berbagai negara. Namun, penelitian-penelitian sebelumnya menunjukkan hasil yang tidak konsisten terkait efektivitasnya dalam pembelajaran matematika. Oleh karena itu, para pendidik memerlukan bukti yang lebih akurat dan komprehensif mengenai pengaruh FLM terhadap kemampuan matematis siswa. Penelitian ini bertujuan untuk melakukan meta-analisis guna menginvestigasi pengaruh keseluruhan FLM terhadap kemampuan matematis siswa serta menganalisis karakteristik penelitian yang dapat memengaruhi efektivitasnya. Meta-analisis ini menganalisis 36 ukuran efek yang diperoleh dari 25 studi yang dipublikasikan pada jurnal terindeks Scopus selama periode 2014–2024. Analisis data dilakukan menggunakan perangkat lunak *Comprehensive Meta-Analysis* (CMA). Hasil penelitian menunjukkan ukuran efek gabungan sebesar 1,35 yang mengindikasikan bahwa FLM memberikan pengaruh positif yang sangat besar terhadap kemampuan matematis siswa. Selain itu, analisis moderator menunjukkan bahwa efektivitas FLM bervariasi berdasarkan jenjang pendidikan, jenis FLM, kapasitas kelas eksperimen, jenis platform yang digunakan, dan jenis kemampuan matematis yang diukur. Temuan ini menunjukkan bahwa FLM dapat menjadi pendekatan pembelajaran yang efektif untuk meningkatkan kemampuan matematis siswa apabila diterapkan pada kondisi pembelajaran yang sesuai.

**Kata Kunci:** *effect size*; model *flipped learning*; kemampuan matematis; meta-analisis; basis data Scopus.

## INTRODUCTION

In the last decade, the Flipped Learning Model (FLM) has become a highly accepted approach in various education systems around the world. With the advancement of digital technology, FLM has transcended traditional class boundaries and provided wider access to education (Ergene & Karaboğaz, 2024; Kustandi et al., 2020). FLM is often associated with improved mathematical academic skills because it gives students the opportunity to study at home at their own rhythm (Bosnić et al., 2022; Ishak et al., 2020), encourages students to take responsibility for their own learning (Ishartono et al., 2022), and allows for better personalization of learning (Yorganci, 2020). The development of the FLM also gives students the opportunity to train problem-solving skills and explore alternative solutions. This is due to flexible learning, which provides extensive access to a wide range of learning resources (Nerantzi, 2020; Wang & Jou, 2020).

The effectiveness of FLM on students' mathematical abilities at various educational levels has been the subject of numerous studies. However, the results of the study show inconsistencies. Some studies show that the use of FLM is more effective in improving students' mathematical skills when compared to conventional learning models (Albalawi, 2018; Algarni & Lortie-Forgues, 2022; Altakhayneh, 2022; Ariani et al., 2022; Bhagat et al., 2016; Casem, 2016; Chimmalee & Anupan, 2023; Diana et al., 2023; Egara, 2023; Esperanza et al., 2016; Hanifah et al., 2023). However, another study found that the use of FLM did not result in a significant improvement (Jarrah & Diab, 2019; Ramadhani et al., 2019). These differences in research results can cause confusion among educational policymakers, especially for mathematics teachers who need accurate and consistent information. Therefore, to investigate the factors that may cause these inconsistencies and to provide clear guidance for the development of learning policies and practices in the field of mathematics, more focused and comprehensive advanced research is required.

To address the inconsistency of research results regarding the effectiveness of the use of FLM in improving students' mathematical abilities, the collection and preparation of various primary research results are required. Quantitative research methods such as meta-analysis studies have become the right choice to provide more accurate information in policymaking (Muhtadi et al., 2022; Setiawan et al., 2022). The special role of meta-analysis studies is to integrate findings from various major studies, as well as identify reasons for result variation to be considered in future practice (Bredow et al., 2021). The meta-analysis provides a deeper and more accurate conclusion about the relationship between the two variables under investigation, compared to a single experimental study (Borenstein et al., 2009). Therefore, meta-analysis studies are essential to conclude more conclusively about the effectiveness of the application of FLM to students' mathematical abilities so that teachers can consider its future application.

Previous meta-analysis research has explored the impact of applying the FLM in the context of mathematics learning (Güler et al., 2023; Purnomo et al., 2022; Sopamena et al., 2023; Sulistyowati et al., 2023; Yakar, 2021). However, these studies generally rely on primary data from various sources such as ERIC, Google Scholar, repositories, and other library databases. Different from previous meta-analysis research approaches, this meta-analysis research uses data obtained from articles registered in the Scopus database. This decision was taken because there was no previous research that explicitly prioritized the use of Scopus as the only search source. In addition, Scopus is favored because of its consistency in applying evaluation standards for documents included in its index (Phan et al., 2022). Scopus is also known to have wider document coverage compared to other leading databases (Hallinger & Chatpinyakoop, 2019; Hallinger & Nguyen, 2020). Furthermore, there has been no meta-analysis research that exclusively focuses on the effectiveness of FLM on students' mathematical abilities by considering specific characteristics such as education level, type of FLM, experimental class capacity, type of platform used, and type of mathematical ability.

This study aims to fill the gaps left by previous studies by focusing on two main objectives: first, to determine the overall effectiveness of the Flipped Learning Model (FLM) in improving students' mathematical abilities; and second, to examine whether the effectiveness of FLM varies according to several research characteristics. Specifically, this study investigates differences in effectiveness based on educational level, type of FLM, experimental class capacity, platform type, and type of mathematical ability. These objectives are intended to provide educators with clearer guidance in identifying the most optimal conditions for implementing FLM to enhance students' mathematical abilities. To achieve these aims, this study employs a meta-analysis approach by synthesizing findings from previous primary studies related to the implementation of FLM in mathematics learning.

## RESEARCH METHOD

This study employed a meta-analysis design to examine the effect of FLM on students' mathematical abilities. The design selection was made with the aim of integrating the findings of previous studies, thus enabling the presentation of a holistic and general picture of the FLM impact. The inclusion criteria for this research include studies that meet the following requirements: (a) Research published between 2014 and 2024; (b) Studies published in Scopus indexed journals; (c) Students at different educational levels participating in mathematics learning using the FLM; (d) Experimental, quasi-experimental, or observational research with a clearly defined control group; (e) Studies reporting data on students mathematical abilities resulting from intervention using the FLM; and (f) Studies were required to provide sufficient statistical data for effect size calculation.In this study, the Scopus database was selected as the relevant document search location. Furthermore, The Publish or Perish (PoP) software was used to retrieve relevant studies from the Scopus database using specific keyword combinations such as "Mathematics, Flipped Learning," "Mathematics, Flipped Classroom," "Algebra, Flipped Learning," and "Calculus, Flipped Learning." For example, Figure 1 describes the process of searching for studies related to the application of FLM in the Scopus database using the PoP application. This search resulted in 198 relevant studies.

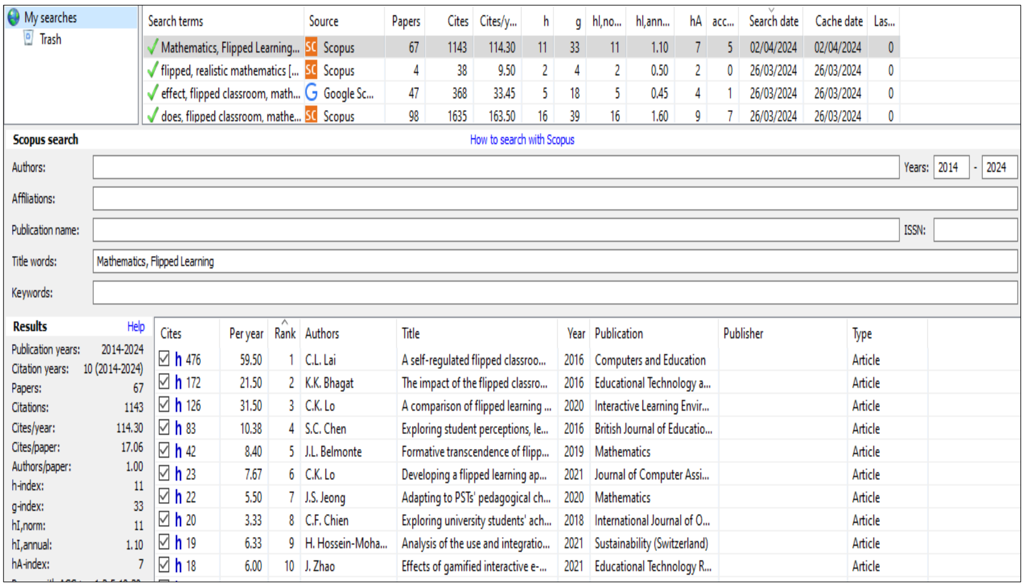


**Figure 1.** The data search process uses the PoP application

Data that meets the inclusion criteria is then encoded. The encoding process in this study involved two assessments to reduce the potential for subjective error. A summary of the encoding results is presented in Table 1 below.

**Table 1.** Coding of studies that meet the inclusion criteria

| Coding Content | Moderator Variable | N |
|---|---|---|
| Educational Level | JHS (Junior High School) | 8 |
| | SHS (Senior High School) | 17 |
| | College | 11 |
| FLM Types | Conventional FL | 24 |
| | Gamification-Based FL | 2 |
| | Geogebra-Based FL | 2 |
| | Inquiry-Based FL | 2 |
| | PBL-Based FL | 4 |
| | RME-Based FL | 2 |
| Experimental Class Capacity | $\leq 30$ | 12 |
| | $> 30$ | 24 |
| Platforms Types | BlackBoard | 1 |
| | Canvas | 2 |
| | DropBox | 1 |
| | Edmodo | 3 |
| | EBA | 2 |
| | Google Classroom | 4 |
| | QQ Learning | 4 |
| | Moodle | 10 |
| | Khan Academy | 3 |
| | WhatsApp | 3 |
| | Not Report | 3 |
| Types of Mathematical Ability | Creative Thinking | 3 |
| | Critical Thinking | 6 |
| | High Order Thinking Skills (HOTS) | 1 |
| | Conceptual Understanding | 2 |
| | Mathematical Reasoning | 2 |
| | Learning Achievement | 20 |
| | Problem Solving | 2 |

Data analysis was conducted using Comprehensive Meta-Analysis (CMA) software. The meta-analysis procedure applied in this study involved several stages: (1) measuring the individual effect sizes to determine the influence of the Flipped Learning Model (FLM) on students' mathematical abilities; (2) calculating the combined effect size and evaluating publication bias; and (3) analyzing moderator variables to identify factors that moderate the influence of FLM on mathematical abilities. The interpretation of effect sizes in assessing the influence of FLM on students' mathematical abilities in this study was based on the classification proposed by Cohen (Cohen et al., 2017). The detailed classification of effect sizes used for interpreting the results is presented in Table 2.

**Table 2.** Category of effect sizes

| Category | Interval |
|---|---|
| Ignored | Effect size ≤ 0.20 |
| Small | 0.20 < Effect size ≤ 0.50 |
| Medium | 0.50 < Effect size ≤ 0.80 |
| Large | 0.80 < Effect size ≤ 1.30 |
| Very Large | Effect size > 1.30 |

Table 2 presents the classification of effect sizes used to interpret the magnitude of the Flipped Learning Model (FLM) influence on students' mathematical abilities. The interpretation follows Cohen's classification criteria (Cohen et al., 2017). Effect sizes less than or equal to 0.20 are categorized as ignored, indicating that the influence of FLM is negligible. Effect sizes between 0.20 and 0.50 are considered small, showing a limited influence. Values between 0.50 and 0.80 are classified as medium, indicating a moderate influence of FLM on students' mathematical abilities. Furthermore, effect sizes ranging from 0.80 to 1.30 are categorized as large, reflecting a substantial influence. Finally, effect sizes greater than 1.30 are interpreted as very large, indicating a very strong influence of FLM on students' mathematical abilities.

## RESULTS AND DISCUSSION

Here is an analysis of the impact of the use of the Flipped Learning Model (FLM) on the student's overall mathematical ability, obtained through calculations with the help of Comprehensive Meta Analysis. (CMA). Effect measurements along with confidence interval limits have been presented in Table 3 below.

**Table 3.** Classification of effect sizes

| Author | Effect Size | Std. Error | Confidence Interval (CI) | |
|---|---|---|---|---|
| | | | Lower Limit | Upper Limit |
| Albalawi (Albalawi, 2018) | 1.97 | 0.25 | 1.47 | 2.46 |
| Algarni & Lortie-Forgues (Algarni & Lortie-Forgues, 2022) | 1.34 | 0.13 | 1.08 | 1.60 |
| Altakhayneh (Altakhayneh, 2022) | 3.47 | 0.24 | 2.99 | 3.94 |
| Ariani et al. a (Ariani et al., 2022) | 2.50 | 0.29 | 1.93 | 3.08 |
| Ariani et al. b (Ariani et al., 2022) | 2.51 | 0.29 | 1.94 | 3.09 |
| Bhagat et al. (Bhagat et al., 2016) | 0.51 | 0.22 | 0.07 | 0.95 |
| Casem (Casem, 2016) | 0.78 | 0.41 | -0.03 | 1.58 |
| Chimmalee & Anupan (Chimmalee & Anupan, 2023) | 0.98 | 0.20 | 0.59 | 1.37 |
| Diana et al. a (Diana et al., 2023) | 2.01 | 0.30 | 1.41 | 2.60 |

| Author | Effect Size | Std. Error | Confidence Interval (CI) | |
|---|---|---|---|---|
| | | | Lower Limit | Upper Limit |
| Diana et al. b (Diana et al., 2023) | 2.69 | 0.34 | 2.02 | 3.36 |
| Egara & Mosimege (Egara, 2023) | 2.25 | 0.27 | 1.71 | 2.78 |
| Esperanza et al (Esperanza et al., 2016) | 0.42 | 0.21 | 0.01 | 0.84 |
| Hanifah et al. a (Hanifah et al., 2023) | 1.90 | 0.29 | 1.33 | 2.47 |
| Hanifah et al. b (Hanifah et al., 2023) | 0.90 | 0.25 | 0.41 | 1.40 |
| Jarrah & Diab a (Jarrah & Diab, 2019) | 0.98 | 0.24 | 0.51 | 1.44 |
| Jarrah & Diab b(Jarrah & Diab, 2019) | 0.97 | 0.24 | 0.51 | 1.43 |
| Jarrah & Diab c (Jarrah & Diab, 2019) | 0.91 | 0.23 | 0.45 | 1.37 |
| Jarrah & Diab d (Jarrah & Diab, 2019) | 0.19 | 0.22 | -0.25 | 0.63 |
| Kavaz & Kocak a (Kavaz & Koçak, 2024) | 3.19 | 0.43 | 2.35 | 4.04 |
| Kavaz & Kocak b (Kavaz & Koçak, 2024) | 2.13 | 0.36 | 1.43 | 2.83 |
| Lo & Hew (Lo & Hew, 2020) | 0.72 | 0.27 | 0.18 | 1.26 |
| Metpattarahiran (Metpattarahiran, 2023) | 1.75 | 0.15 | 1.45 | 2.05 |
| Nguyen et al. (Nguyen et al., 2023) | 0.61 | 0.24 | 0.15 | 1.07 |
| Ramadhani, Umam et al. (Ramadhani et al., 2019) | 0.11 | 0.25 | -0.38 | 0.60 |
| Ramadhani, Bina et al. (Ramadhani et al., 2020) | 1.24 | 0.28 | 0.69 | 1.79 |
| Spotts & Blumme a (Spotts & Blume, 2020) | 1.11 | 0.32 | 0.48 | 1.73 |
| Spotts & Blumme b (Spotts & Blume, 2020) | 0.70 | 0.31 | 0.10 | 1.30 |
| Supriadi et al. (Supriadi et al., 2021) | 1.79 | 0.29 | 1.22 | 2.37 |
| Syam et al. (Syam et al., 2016) | 2.20 | 0.26 | 1.69 | 2.72 |
| Tabieh & Hamzeh a (Tabieh & Hamzeh, 2022) | 1.27 | 0.12 | 1.04 | 1.50 |
| Tabieh & Hamzeh b (Tabieh & Hamzeh, 2022) | 1.03 | 0.11 | 0.81 | 1.25 |
| Wei et al (Wei et al., 2020) | 0.62 | 0.22 | 0.20 | 1.05 |
| Yohannes & Chen a (Yohannes & Chen, 2024) | 0.39 | 0.26 | -0.11 | 0.90 |
| Yohannes & Chen b (Yohannes & Chen, 2024) | 1.00 | 0.27 | 0.47 | 1.53 |
| Zhao et al. a (Zhao et al., 2021) | 0.94 | 0.27 | 0.41 | 1.47 |
| Zhao et al. b (Zhao et al., 2021) | 1.25 | 0.28 | 0.70 | 1.79 |

Table 3 depicts a range of overall effect measurements ranging from 0.11 to 3.47, with a 95% confidence rate. Meanwhile, Figure 2 visualizes the level of impact measurement of the entire study, referring to the classification of Cohen et al. (Cohen et al., 2017).

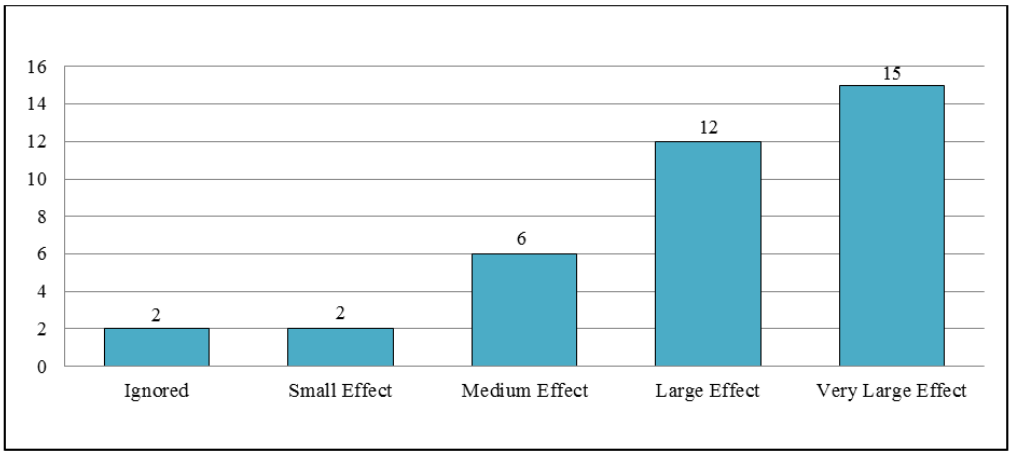


**Figure 2.** The Number of effect Sizes

Figure 2 shows the variation in the measurement of the effects resulting from research on the application of the FLM in mathematical learning. Meanwhile, Table 4 presents the results of the meta-analysis in a descriptive manner based on estimated methods.

**Table 4.** Heterogeneity testing and pooled effect sizes

| Estimation Method | N | Mean | P | Df | Heterogeneity | | | Decision |
|---|---|---|---|---|---|---|---|---|
| | | | | | Q | p | I2 | |
| Random-Effect | 36 | 1.35 | 0.00 | 35 | 343.49 | 0.00 | 89.81% | Reject H0 |
| Fixed-Effect | 36 | 1.25 | 0.00 | 35 | | | | |

Methods for estimating the measurement of combined size effects are determined on the basis of heterogeneity tests. The results of the heterogeneity test (see Table 4) showed a Q-value of 343.49 $> \chi^2$ (df = 35; p = 0.05). This indicates that the spread of data measurement effects between studies is heterogeneous. Since the spread of measurement of effects between studies is heterogeneous, therefore, the random-effects model was used to estimate the pooled effect size.

Based on the random-effects model presented in Table 4, the pooled effect size was 1.35 with a 95% confidence interval, indicating a very large effect. In addition, the significance test produced a p-value of less than 0.001, suggesting that the implementation of the Flipped Learning Model (FLM) results in significantly better mathematical abilities compared to conventional learning models. These findings indicate that FLM has a stronger and more meaningful impact on students' mathematical abilities than traditional instructional approaches. Referring to Coe's (2002) interpretation of effect size, this result implies that, on average, students who experienced FLM outperformed approximately 88% of students in conventional classrooms with similar initial ability levels. In practical terms, a student ranked 13th in the FLM group would achieve performance comparable to a student ranked 3rd in the conventional group. Therefore, these findings provide strong evidence that the implementation of FLM offers substantial benefits in enhancing students' mathematical abilities.

The results of this meta-analysis are in line with previous findings by Cheng et al. (Cheng et al., 2019), Purnomo et al. (Purnomo et al., 2022), Wagner et al. (Wagner et al., 2020), and Yakar. (Yakar, 2021). Although their research is not focused on doing meta-analyses of studies derived from the scopus data base, all of these studies conclude that the application of FLM has a significant impact on student learning outcomes. The consistent results obtained from many studies provide additional support and validation to advocate the use of the FLM as an effective method to improve students' mathematical skills.

To determine whether there is systematic bias in the selection of research included in the meta-analysis, we further evaluate the bias of publication. Publication bias occurs when research that has a positive outcome is more likely to be published than research that has a non-significant or negative outcome. It could make mistakes in the interpretation and the decisions taken from the research. The fail-Safe N (FSN) approach to determining publication bias. Figure 3 shows the results.

**Classic fail-safe N**

| | |
|---|---|
| Z-value for observed studies | 34,54305 |
| P-value for observed studies | 0,00000 |
| Alpha | 0,05000 |
| Tails | 2,00000 |
| Z for alpha | 1,95996 |
| Number of observed studies | 36,00000 |
| Number of missing studies that would bring p-value to > alpha | 1147,00000 |

**Figure 3.** FSN results

With target significance values ($\alpha = 0.05$) and $p < 0.001$, these results show that despite a number of unpublished studies, remains statistically significant. Therefore, we can conclude that this meta-analysis has a high degree of security against publication bias, and the results are considered scientifically valid. In other words, even though there are additional studies that have not been published or the results are insignificant, this will not change the conclusions of this meta-analysis as a whole.

**Table 5.** Effect sizes by education level

| Education Level | N | Effect Size | P | Heterogeneity | | | Decision |
|---|---|---|---|---|---|---|---|
| | | | | df | Qb | P | |
| JHS | 8 | 1.33 | 0.00 | 2 | 75.51 | 0.00 | Reject H0 |
| SHS | 17 | 1.00 | 0.00 | | | | |
| College | 11 | 1.76 | 0.00 | | | | |

Table 5 reveals that the Q statistical value for the homogeneity test is 75.51, which is greater than 5.99 ($df = 2$; $p = 0.05$) in the $\chi 2$ tables. These findings suggest that the distribution of effect sizes is varied. This suggests that the impact of mathematical skill utilizing FLM varies greatly depending on educational level. The data revealed that the use of FLM to increase mathematical skills was most beneficial in tertiary institutions compared to JHS and SHS. These results are similar to those of earlier meta-analyses by Cheng et al. (Cheng et al., 2019), Güler et al. (Güler et al., 2023), and Vitta and Al-Hoorie (Vitta & Al-Hoorie, 2023), which also found that the level of education has a big impact on how FLM use affects students' academic performance. Despite the large disparities, the findings of the investigation confirm that the use of FLM has a significant impact on all educational levels.

**Table 6.** Effect sizes based on FLM type

| FLM Type | N | Effect Size | P | Heterogeneity | | | Decision |
|---|---|---|---|---|---|---|---|
| | | | | df | Qb | P | |
| Conventional FL | 24 | 1.24 | 0.00 | 5 | 48.59 | 0.00 | Reject H0 |
| Gamification-Based FL | 2 | 0.98 | 0.00 | | | | |
| Geogebra-Based FL | 2 | 2.51 | 0.00 | | | | |
| Inquiry-Based FL | 2 | 1.12 | 0.00 | | | | |
| PBL-Based FL | 4 | 1.32 | 0.00 | | | | |
| RME-Based FL | 2 | 0.68 | 0.00 | | | | |

Table 6 reveals that the Q statistical value for the homogeneity test is 48.59, which is greater than 11.07 (df = 5, p = 0.05) in the $\chi 2$ table. These findings suggest that the distribution of effect sizes is varied. This suggests that the extent of the effect of mathematical aptitude on FLM varies greatly depending on the type of FLM. In other words, the efficiency of using FLM varies according to the type of FLM. The Geogebra-Based FL type found FLM to be the most effective, followed by PBL-Based FL, Conventional FL, Inquiry-Based FL, Gamification-Based FL, and finally RME-Based PBL. We could attribute these variances to variations in the structures applied by each FLM type. For example, geogebra-based FL may be more effective since it employs interactive geogebra software and allows for dynamic depiction of mathematical concepts. More research is necessary to identify the elements that contribute to the variances in effectiveness among different types of FLM. Even if there are considerable disparities between the FLM type groups, the study results clearly show that all types of FLM have a major impact on mathematical abilities.

**Table 7.** Effect sizes based on experimental class capacity

| Experimental Class Capacity | N | Effect Size | P | Heterogeneity | | | Decision |
|---|---|---|---|---|---|---|---|
| | | | | df | Qb | P | |
| ≤ 30 | 12 | 1.30 | 0.00 | 1 | 13.96 | 0.00 | Reject H0 |
| > 30 | 24 | 0.94 | 0.00 | | | | |

Table 7 indicates that the Q statistical value for the homogeneity test is 13.96, which is higher than 3.84 (df = 1; p = 0.05) in the $\chi 2$ table. These findings suggest that the distribution of effect sizes is varied. This suggests that the magnitude of the effect of mathematical skill utilizing FLM varies greatly depending on the capacity of the experimental group. This suggests that a lower class size has a greater impact on the use of FLM. Previous research by Mawardi et al. (Mawardi et al., 2023), Samritin et al. (Samritin et al., 2023), and Turgut and Turgut (Turgut & Turgut, 2018), which found that small study groups are more effective, is similar to this finding. Cheung and Slavin (Cheung & Slavin, 2013) observed that study groups with large samples had larger effect sizes than study groups with small samples. Therefore, we must further examine these variations to identify the elements that could potentially influence these findings. This indicates that we need to further investigate discrepancies in opinion or results from earlier research to gain a more comprehensive and accurate understanding of the relationship between classroom capacity and FLM efficacy. Even though they differ greatly in their use of FLM, FLM has a major impact on both.

**Table 8.** Effect Sizes by platform type

| Platform Type | N | Effect Size | P | Heterogeneity | | | Decision |
|---|---|---|---|---|---|---|---|
| | | | | df | Qb | P | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| BlackBoard | 1 | 2.20 | 0.00 | | | | |
| Canvas | 2 | 2.30 | 0.00 | | | | |
| DropBox | 1 | 0.51 | 0.02 | | | | |
| Edmodo | 3 | 2.89 | 0.00 | | | | |
| EBA | 2 | 2.56 | 0.00 | | | | |
| Google Classroom | 4 | 0.90 | 0.00 | 10 | 216.98 | 0.00 | Reject H0 |
| Khan Academy | 4 | 0.75 | 0.00 | | | | |
| Moodle | 11 | 1.41 | 0.00 | | | | |
| QQ Learning | 3 | 0.67 | 0.00 | | | | |
| WhatsApp | 3 | 0.79 | 0.00 | | | | |
| Not Report | 3 | 1.33 | 0.00 | | | | |

Tabel 8 shows that the statistic Q uji homogenitas is 216.98, which is higher than 18.31 (df = 10; p = 0.05) in table χ2. The results show that the distribution of effect size is heterogeneous. As a result, the benefit of using FLM differs significantly depending on the platform type. In other words, the efficiency of adopting FLM varies according to the platform employed. We determined that the Edmodo platform yields the most effective FLM adoption, followed by EBA, Canvas, BlackBoard, Moodle, Google Classroom, WhatsApp, Khan Academy, QQ Learning, and DropBox. Purnomo et al. (Purnomo et al., 2022) conducted a recent meta-analysis that aligns with these findings. Despite the meta-analysis focusing solely on Indonesian research, the findings remain consistent and align with the overall trend. To gain more comprehensive information, additional research is required to understand the factors behind variances in effectiveness amongst platform types. Despite the vast disparities across platform type groupings, FLM has a significant impact on all types of platforms used.

**Table 9.** Effect Sizes by type of mathematical abilities

| Type of Mathematical Abilities | N | Effect Size | P | Heterogeneity | | | Decision |
|---|---|---|---|---|---|---|---|
| | | | | df | Qb | P | |
| Creative Thinking | 3 | 1.24 | 0.00 | | | | |
| Critical Thinking | 6 | 1.36 | 0.00 | | | | |
| HOTS | 1 | 2.68 | 0.00 | | | | |
| Conceptual Understanding | 2 | 1.03 | 0.00 | 6 | 100.37 | 0.00 | Reject H0 |
| Mathematics Reasoning | 2 | 2.78 | 0.00 | | | | |
| Learning Achievement | 20 | 1.06 | 0.00 | | | | |
| Problem Solving | 2 | 1.35 | 0.00 | | | | |

Table 9 reveals that the Q statistical value for the homogeneity test is 100.37, which is greater than 12.59 (df = 6; p = 0.05) in the χ2 table. These findings suggest that the distribution of effect sizes is varied. This suggests that the extent of the impact of mathematical ability on FLM varies greatly depending on the type of mathematical aptitude. In other words, the efficacy of employing FLM may vary depending on the measured mathematical abilities. We determined that FLM was the most beneficial for mathematical reasoning, followed by HOTS, critical thinking, creative thinking, general learning achievement, and, finally, conceptual comprehension. The previous meta-analysis by Sulistyowati et al. (Sulistyowati et al., 2023) and Mawardi et al. (Mawardi et al., 2023), which found that the type of mathematical skill tested determines the extent of the effect, is also consistent with these findings. The earlier study's synthesized meta-analysis item only encompasses papers published in Indonesia, yet it yields remarkably comparable conclusions.

Despite large disparities between groups of abilities assessed, FLM has a significant impact on all sorts of mathematical abilities.

The findings revealed that GeoGebra-based flipped learning produced the highest effect size among all FLM types. This result may be attributed to the interactive and dynamic features of GeoGebra, which enable students to visualize abstract mathematical concepts more effectively and explore mathematical relationships through direct manipulation. Such learning experiences are closely aligned with constructivist theory, which emphasizes that knowledge is actively constructed by learners through exploration, interaction, and meaningful learning experiences. By integrating GeoGebra into the flipped learning environment, students are provided with opportunities to build conceptual understanding independently before participating in collaborative classroom discussions and problem-solving activities.

In addition, the high effectiveness of GeoGebra-based FLM may also be associated with increased cognitive engagement. Interactive mathematical visualizations encourage students to actively analyze, interpret, and evaluate mathematical representations rather than passively receiving information. This active involvement enhances deeper conceptual processing and supports higher-order thinking skills. Furthermore, the flipped learning environment promotes self-regulated learning because students are required to manage their own learning pace, review instructional materials independently, and prepare themselves before classroom activities. Students who develop stronger self-regulation skills are more likely to achieve better mathematical performance in technology-supported learning environments.

From the perspective of technology integration theory, the effectiveness of GeoGebra-based FLM demonstrates how appropriate integration of digital technology can enhance instructional quality and learning outcomes. Technology in mathematics education is most effective when it is not merely used as a supplementary tool, but when it actively supports conceptual understanding, interaction, and student-centered learning processes. Therefore, the integration of GeoGebra within the flipped learning model creates a learning environment that combines technological support, active learning, and collaborative engagement, leading to improved mathematical abilities.

## CONCLUSION

This study revealed that the Flipped Learning Model (FLM) has a significant positive effect on students’ mathematical abilities, with effectiveness influenced by educational level, FLM type, class size, platform, and type of mathematical ability. GeoGebra-based FLM and Edmodo platform showed the highest effectiveness, while FLM was most effective in improving mathematical reasoning skills. These findings highlight the importance of instructional design and meaningful technology integration in mathematics learning. However, this study was limited by the exclusion of several studies and the analysis of only a few moderator variables. Therefore, future research should examine additional factors to provide a more comprehensive understanding of FLM effectiveness in mathematics education.

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