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Effectiveness of Geogebra Integration into Flipped Classroom (GFC) on Students Mathematics Skills: A Meta-Analysis Study

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Abstract: Effectiveness of Geogebra Integration into Flipped Classroom (GFC)on Students Mathematics Skills: A Meta-Analysis Study. Previous research examining the effectiveness of Geogebra Integration into Flipped Classroom (GFC) on students' mathematics skills showed inconsistent results. **Objectives:** This research aims to conduct a meta-analysis study on the effectiveness of Geogebra integration into Flipped Classroom (GFC) and identify what factors moderate the effect of GFC on students' mathematical skills. **Methods:** The research method used meta-analysis. The samples in this study were 31 primary studies that met the specified inclusion criteria. Data analysis was conducted using comprehensive meta-analysis (CMA) software. **Findings:** The results of the analysis using the random-effects approach showed that the combined effect size was ($g = 1.06$; $p < 0.01$) (Large Effect Category). This indicates that GFC has a significant influence on students' mathematics skills. The result of moderator variable analysis shows that the effect of GFC implementation on students' mathematics skills is significantly different based on the variable of platform used ($Qb = 21.98$; $p = 0.01$), and publication type ($Qb = 7.94$; $p = 0.01$). However, it was not significantly different based on the variables of education level ($Qb = 7.45$; $p = 0.06$), experimental group capacity ($Qb = 0.29$; $p = 0.62$), and year of publication ($Qb = 0.21$; $p = 0.64$). The findings of this meta-analysis can serve as a basis for best practices in applying GFC to student mathematics skills **Conclusion:** The findings of this meta-analysis provide more accurate and comprehensive results regarding the inconsistent effects of size variation and enrich knowledge about the effectiveness of using GFC in improving students' mathematics skills.

Keywords: geogebra into flipped classroom, mathematics skill, meta-analysis.

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INTRODUCTION

The integration of GeoGebra into the Flipped Classroom (GFC) learning model is not a new thing in mathematics education innovation aimed at supporting students' mathematical abilities (Ishartono et al., 2022; Salami & Spangenberg, 2024; Weinhandl et al., 2020). Flipped Classroom itself is an approach where traditional learning is reversed, with students studying the subject matter independently at home through videos or reading materials, and class time is used for more interactive activities such as discussions, problem solving, or experiments (Baniyah et al., 2023; Ettien & Touré, 2023; Gustian et al., 2023; Yusuf & Taiye, 2021). This approach allows students to learn more varied and flexible because learning is not limited to when students are at school. Flipped Classroom also provides wider learning opportunities and attracts students' interest in learning (Varghese & Saravanakumar, 2022). Therefore, the flipped classroom is very potential to be integrated with other components that can optimize the learning approach to students, one of which is by integrating Geogebra in the Flipped Classroom.

GeoGebra which is a dynamic-based mathematical software that combines geometry, algebra, calculus, and statistics, has been proven to improve understanding of mathematical concepts through visualization and direct manipulation of mathematical objects (Juandi et al., 2021; Maududi et al., 2021; Simbolon & Siahaan, 2021; H. M. Siregar et al., 2024). In the context of the Flipped Classroom, GeoGebra can be a very useful tool to enrich students' learning experiences outside the classroom (Dahal et al., 2022; Selvy et al., 2020). For example, students can use GeoGebra at home to explore and interact with mathematical concepts such as functions, graphs, geometry or statistics. This allows them to visualize mathematical abstractions in a more concrete and interactive way. When students come to class, they already have a basic understanding of the topic and can focus on more in-depth discussions, applications, and problem solving, guided by the teacher.

Several studies show that the use of GeoGebra in a flipped classroom can accelerate students' understanding of mathematical concepts, as they can learn at their own pace and gain a better understanding through visualization. For example, studies suggest that the integration of GeoGebra in a flipped classroom helps students understand more complex topics, such as geometry and calculus, in a more intuitive and easy-to-understand way (Lestari et al., 2023; Syarifah & Yasin, 2024). Another study also found that students who engaged in GeoGebra-based learning showed a significant increase in understanding of mathematical concepts compared to students who followed traditional learning (Nurdin et al., 2019; Rohim & Buchori, 2024).

Until now, students' mathematical ability supported by geogebra integration into flipped classroom (GFC) has been widely studied by researchers in various countries. Some studies have confirmed that GFC has a positive effect on student mathematic skills (Albalawi, 2018; Andriani et al., 2022; Casem, 2016; Li et al., 2017; Luis & Soto, 2023; Maciejewski, 2018; Peterson, 2016; Schroeder et al., 2015; Zeineddine, 2018). However, some other studies state that GFC has'nt a significant effect on students mathematic skills (Crawford, 2017; Dixon, 2017; Jackson, 2019; Montgomery, 2015). These results show various inconsistent research results. On the other hand, education policy makers, especially mathematics teachers, need accurate information on best practices in implementing GFC.

Differences in research results can be caused by variations in implementation methods, learning contexts, or different student characteristics in each lesson. Davies (2000) said that a single experiment has certain limitations, such as time, sample, and context, which can explain the differences in research results. Therefore, contradictions between research findings can be understood as a reflection of the diversity of conditions in the field. To overcome this problem, it is necessary to conduct a meta-analysis study as an approach that can unify the findings of different research results (Borenstein et al., 2009; Hunter, J. E. & Schmidt, 2004). Meta-analysis is a quantitative research method that analyzes various studies that have been conducted previously to determine the strength of the relationship between several variables with statistical analysis using certain measures, such as effect size (Borenstein et al., 2009). By harmonizing data from various studies, meta-analysis can provide a broader and more reliable picture of the impact of GFC on student mathematic skills.

Some previous meta-analysis studies on the effect of GFC on students' mathematic skills still have some weaknesses. Publication bias and sensitivity analysis are needed to ensure the quality of a study (Mathur & VanderWeele, 2020). However, there are still some meta-analysis studies that have not analyzed publication bias and sensitivity (Nurtamam et al., 2023). Then, the size of the combined effect tends to be over-interpreted and does not reflect the true effect. Investigation of moderator variables is necessary in analyzing the heterogeneity of meta-analysis results. However, some meta-analysis studies related to GFC on students' mathematic skills have not investigated moderator variables such as the platform used in GFC, education level, experimental group capacity, experimental group type, publication year, and publication type. These characteristics might affect the heterogeneity of effect sizes but were not investigated and analyzed. Therefore, this study aims to summarize, estimate and evaluate the overall impact of GFC on students' mathematic skills.

The results of this meta-analysis study are expected to provide more precise guidance for educational policy makers, especially mathematics teachers, in implementing best practices in mathematics learning. By identifying moderator variables that might influence the effect of GFC on students' mathematic skills, this study can provide deeper insights into the factors that need to be considered in designing GFC to maximize students' mathematic skills. Thus, this study not only makes a significant theoretical contribution in the understanding of the relationship between the GFC learning model and students' mathematic skills, but also provides relevant practical implications for educational practitioners.

METHOD

Research design

This study used a meta-analysis design to examine the effect of integration GeoGebra into Flipped Classroom (GFC) on students' mathematic skills in mathematics learning. Meta-analysis is a research method for systematically combining and synthesizing findings from multiple quantitative studies in a research domain (Paul & Barari, 2022). The goal is to determine whether effect relationships are consistent across these studies (Brüggemann & Rajguru, 2022) and complex decisions can be supported by robust meta-analysis techniques (Jager et al., 2022). This design was chosen to integrate the findings that have been produced by previous studies, thus allowing a holistic and general picture of the impact of GFC to be presented.

Criteria Inclusion and Data Collection

The inclusion criteria of this study include studies that meet the following requirements: 1) Research published from 2016 to 2023; 2) Students at various levels of education who participated in mathematics learning using GFC; 3) Experimental, quasi-experimental, or observational studies with a clear control group; 4) Studies that reported data related to students' mathematic skills as a result of the intervention using GFC; 5) Studies were available in English to facilitate understanding and analysis; and 6) Studies had to report sufficient statistical data to calculate effect sizes.

Data were obtained from studies that met the inclusion criteria by searching relevant academic databases and international journals. The keywords used included "integration of PBL and FC" AND "Mathematics Problem Solving

Skills". In addition, literature selection was conducted to obtain information from relevant sources that may not be included in the database. From the results of the research search based on the specified criteria, 31 primary studies were found from a total of 167 collected studies. The preliminary data collected was then filtered through four stages, namely identification, screening, eligibility and inclusion. Screening Process literature can be seen in figure 1 below.

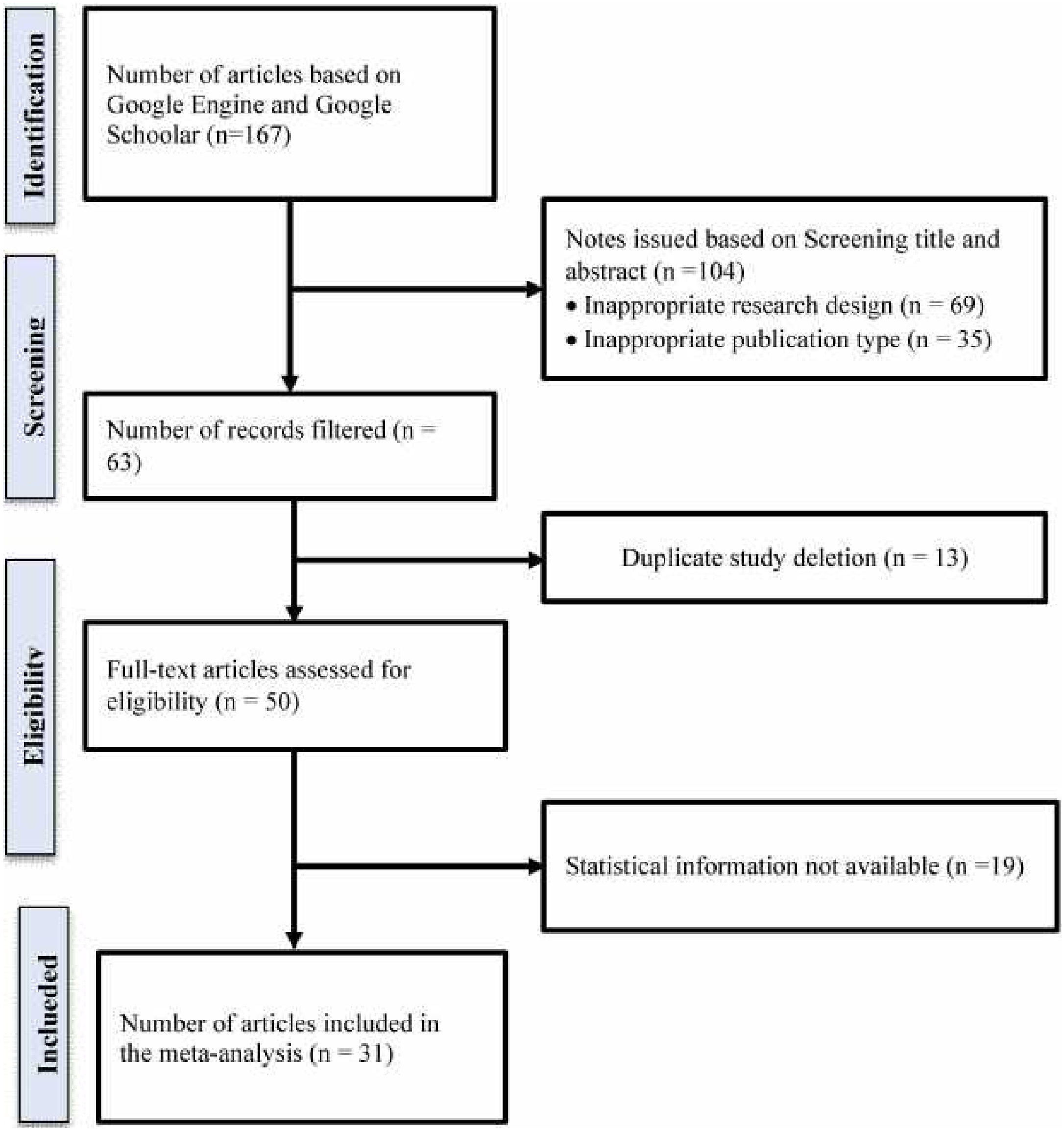


Figure 1. Screening process the literature uses PRISMA

One effective way to minimize bias is to use two independent raters in the literature selection process (Drucker et al., 2016). In the first stage, both raters independently reviewed the titles and abstracts of the literature found to assess whether it met the predefined inclusion criteria. If there was disagreement between them, the literature was either discussed further or moved to the full-text review stage. At this stage, both raters again assessed the articles separately to ensure eligibility. In addition, the use of statistical tools such as the kappa statistic to measure inter-rater agreement is helpful in assessing consistency between raters. The process also includes very detailed recording and reporting of the amount of literature screened and the reasons for exclusion, which is reported through the PRISMA Flow Diagram in Figure 1.

The identification of the characteristics of literary works was done through the coding process. The coding in this study was conducted by two raters to avoid subjective errors. The codi content included information such as education level, capacity of the experimental group, type of experimental group, and platform used in GFC. A summary of the coding is presented in Table 1.

Tabel 1. Coding of studies meeting inclusion criteria

Coding Content	Moderator Variable	Frequency (%)
Eduactional Level	Elementary school (ES)	2 (4.76%)
	Junior High School (JHS)	13 (30.95%)
	Senior High School (SHS)	19 (45.24%)
	College	8 (19.05%)
Experimental Group Capacity	≤ 30	14 (33.33%)
	> 30	28 (66.67%)
Platforms	Edmodo	1 (2.38%)
	Google Classroom	7 (16.67%)
	Khan Academy	4 (9.52%)
	Moodle	6 (14.29%)
	QQ Learning	1 (2.38%)
	WhatsApp	15 (35.71%)
	Not reported	8 (19.05%)
Year of Publication	2016-2019	17 (40.48%)
	2020-2023	25 (59.52%)
Type of Publication	Journal	39 (92.86%)
	Proceedings	3 (7.14%)

Data Analysis

Data were analyzed using Comprehensive Meta Analysis (CMA) software. The meta-analysis scheme applied involved several stages, namely: 1) Calculating the effect size of each study regarding the effect of GFC on student mathematic skills; 2) Calculating the combined effect size and evaluating publication bias; 3) Moderator variable analysis to identify factors that moderate the effect.

Meanwhile, the effect size interpretation process in this study refers to the classification proposed by Cohen et al. (2018). The effect size classification used for interpretation of the results is detailed in Table 2.

Table 2. Classification of effect sizes (g)

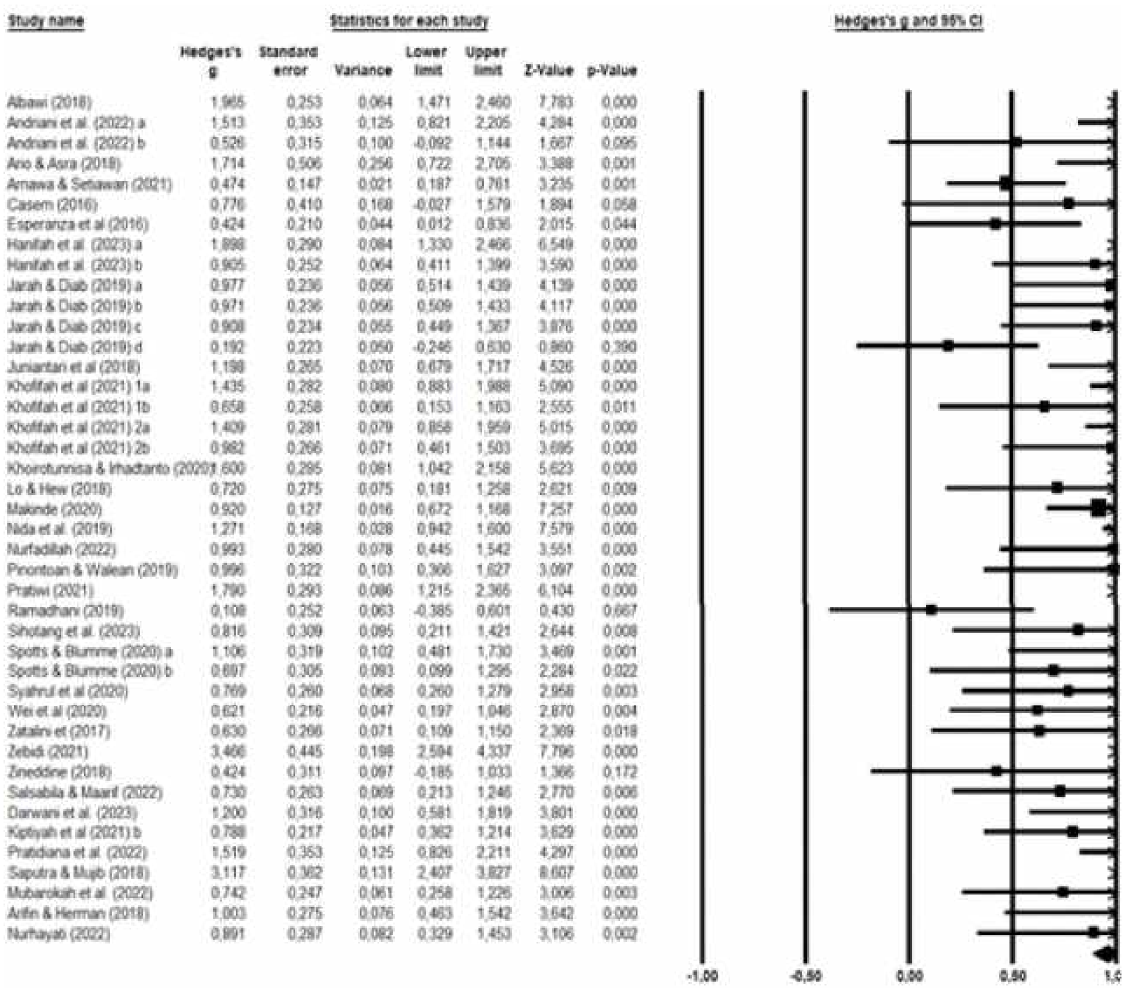
Classification	Interval
Ignored	$0.00 < g \leq 0.19$
Small	$0.19 < g \leq 0.49$
Medium	$0.49 < g \leq 0.79$
Large	$0.79 < g \leq 1.29$
Very Large	$g > 1.29$

■ RESULT AND DISCUSSION

Main Analysis

The effect sizes of the studies were calculated using Comprehensive Meta-Analysis (CMA) Version 3 software. Figure 2 presents a summary of the effect sizes for each study

The vertical line in the middle represents the pooled effect size value. The widened horizontal line on each study reflects the level of uncertainty or 95% confidence interval (CI). Each point on the vertical line represents the effect size result for one study. If a study's confidence interval



Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Albawi (2018)	1,965	0,253	0,064	1,471	2,460	7,783	0,000
Andriani et al. (2022) a	1,513	0,353	0,125	0,821	2,205	4,284	0,000
Andriani et al. (2022) b	0,526	0,315	0,100	-0,092	1,144	1,667	0,095
Ario & Asra (2018)	1,714	0,506	0,256	0,722	2,705	3,388	0,001
Arnawa & Setiawan (2021)	0,474	0,147	0,021	0,187	0,761	3,235	0,001
Casem (2016)	0,776	0,410	0,168	-0,027	1,579	1,894	0,058
Esperanza et al (2016)	0,424	0,210	0,044	0,012	0,836	2,015	0,044
Hanifah et al. (2023) a	1,898	0,290	0,084	1,330	2,466	6,549	0,000
Hanifah et al. (2023) b	0,905	0,252	0,064	0,411	1,399	3,590	0,000
Jarah & Diab (2019) a	0,977	0,236	0,056	0,514	1,439	4,139	0,000
Jarah & Diab (2019) b	0,971	0,236	0,056	0,509	1,433	4,117	0,000
Jarah & Diab (2019) c	0,908	0,234	0,055	0,449	1,367	3,876	0,000
Jarah & Diab (2019) d	0,192	0,223	0,050	-0,246	0,630	0,860	0,390
Juniantari et al (2018)	1,198	0,265	0,070	0,679	1,717	4,526	0,000
Khofifah et al (2021) 1a	1,435	0,282	0,080	0,883	1,988	5,090	0,000
Khofifah et al (2021) 1b	0,658	0,258	0,066	0,153	1,163	2,555	0,011
Khofifah et al (2021) 2a	1,409	0,281	0,079	0,858	1,959	5,015	0,000
Khofifah et al (2021) 2b	0,982	0,266	0,071	0,461	1,503	3,695	0,000
Khoirotunnisa & Irhadtanto (2020)	1,600	0,285	0,081	1,042	2,158	5,623	0,000
Lo & Hew (2018)	0,720	0,275	0,075	0,181	1,258	2,621	0,009
Makinde (2020)	0,920	0,127	0,016	0,672	1,168	7,257	0,000
Nida et al. (2019)	1,271	0,168	0,028	0,942	1,600	7,579	0,000
Nurfadillah (2022)	0,993	0,280	0,078	0,445	1,542	3,551	0,000
Pinontoan & Walean (2019)	0,996	0,322	0,103	0,366	1,627	3,097	0,002
Pratiwi (2021)	1,790	0,293	0,086	1,215	2,365	6,104	0,000
Ramadhani (2019)	0,108	0,252	0,063	-0,385	0,601	0,430	0,667
Sihotang et al. (2023)	0,816	0,309	0,095	0,211	1,421	2,644	0,008
Spotts & Blumme (2020) a	1,106	0,319	0,102	0,481	1,730	3,469	0,001
Spotts & Blumme (2020) b	0,697	0,305	0,093	0,099	1,295	2,284	0,022
Syahrul et al (2020)	0,769	0,260	0,068	0,260	1,279	2,958	0,003
Wei et al (2020)	0,621	0,216	0,047	0,197	1,046	2,870	0,004
Zatalini et (2017)	0,630	0,266	0,071	0,109	1,150	2,369	0,018
Zebidi (2021)	3,466	0,445	0,198	2,594	4,337	7,796	0,000
Zineddine (2018)	0,424	0,311	0,097	-0,185	1,033	1,366	0,172
Salsabila & Maarif (2022)	0,730	0,263	0,069	0,213	1,246	2,770	0,006
Darwani et al. (2023)	1,200	0,316	0,100	0,581	1,819	3,801	0,000
Kiptiyah et al (2021) b	0,788	0,217	0,047	0,362	1,214	3,629	0,000
Pratidiana et al. (2022)	1,519	0,353	0,125	0,826	2,211	4,297	0,000
Saputra & Mujib (2018)	3,117	0,362	0,131	2,407	3,827	8,607	0,000
Mubarokah et al. (2022)	0,742	0,247	0,061	0,258	1,226	3,006	0,003
Arifin & Herman (2018)	1,003	0,275	0,076	0,463	1,542	3,642	0,000
Nurhayati (2022)	0,891	0,287	0,082	0,329	1,453	3,106	0,002

Figure 2. Forest plot

intersects with the vertical line, then the study's effect is considered insignificant. Conversely, if it does not intersect then the effect is considered significant. The length of the line represents the sample size of the study. The longer the line, the larger the sample size. The size of the points indicates the relative weight of the study in the calculation of the combined effect. Studies with greater weight contributed more to the combined results. Of the 42 effect sizes analyzed, the lowest effect size was 0.11, while the highest effect size was 3.47.

If classified according to the scheme of Cohen et al. (2018) there were eleven studies with very large effects, sixteen studies with large effects, ten studies with moderate effects, three studies with small effects, and two studies with negligible effects. This finding shows that there is a variation of effect size in the use of GFC on students' mathematic skills. Therefore, to obtain a more accurate conclusion, it is necessary to calculate the combined effect size. Table 3 summarizes heterogeneity test and the estimation model of random effects and fixed effects.

Table 3. Summary of combined effect size calculations

Model	N	g	P	Df	Heterogeneity		
					Q	p	I^2
Random-Effect	42	1.06	< 0.01	41	180.210	< 0.05	78.25%
Fixed-Effect	42	0.97	< 0.01	41			

The estimation model used to assess the pooled effect size was adjusted according to the results of the heterogeneity analysis. The results of the heterogeneity analysis (see table 4) obtained a p value <0.05. This value indicates that the assumption of heterogeneity is met so that the random effect estimation model is used. The combined effect size based on random effect estimation model was ($g = 1.06$; $p < 0.01$), with large effect category. It can be concluded that the application of GFC has a positive effect on students' mathematic skills. This finding is in line with the findings of previous meta-analysis conducted by Wei et al. (2020), Sappaile et al. (2020), Yakar (2021) who also found that the application of GFC made a significant contribution to student learning outcomes. The consistency of the findings provides more strength and credibility in recommending the implementation of GFC as an effective approach to improve students' mathematic skills.

GFC opens the door to improve students' mathematic skills innovatively and effectively. By presenting learning materials outside the classroom through videos or independent materials, students are given more control over their learning process. They can access and understand the material at their own pace, allowing for a deeper understanding of concepts. This creates a strong foundation for the development of higher-order thinking skills, especially in content mastery and conceptual understanding (Limniou et al., 2018). The process of open discussion and collaboration in the classroom with more optimized time can stimulate mathematical communication and the use of cognitive and metacognitive strategies (Binoy, 2024). In addition, GFC provides sufficient time for students to explore mathematics and conduct investigations outside the classroom, so that they are better prepared when discussing in class (Jdaitawi, 2020). By utilizing GFC, students are not only the recipients of information, but also the main actors in the learning process. They learn to apply knowledge, discuss openly, and undergo investigative experiences. This innovation not only stimulates students' mathematic skills development but also creates a learning environment that is dynamic, relevant, and prepares students for real-life math challenges.

In addition, we also evaluated the possibility of publication bias in the studies we included. We used the file-safe N (FSN) method to evaluate the possibility of publication bias. Fail-Safe N (FSN) is a measure that indicates the number of unpublished studies or insignificant results required for the pooled effect size to be insignificant. The results of the Fail-Safe N (FSN) test are documented in Table 4.

Table 4. Publication bias test results

P	0.00
Alpha	0.05
z for Alpha	1.96
N	42
P > number of missing studies	6888

With a target significance value (á = 0.05) and $p < 0.001$, these results indicate that despite the presence of a number of unpublished studies, a statistically significant combined effect was maintained. Therefore, it can be concluded that this meta-analysis has a high degree of safety against the issue of publication bias, and the results can be considered scientifically valid. In other words, even if there are additional studies that have not been published or the results are not significant, this will not change the overall conclusion of this meta-analysis.

Effectiveness of GFC on students' Math Skills on Moderator Variable Analysis

Next, we conducted a moderator variable analysis to identify factors that may influence the effectiveness of GFC on students' mathematic skills. Table 6 presents a summary of the moderator variable analysis.

Table 6. Results of moderator variable analysis

Moderator Variable	N	g	Standar Error	P	Heterogeneity			
					Q	Df	Qb	P
Education Level								
ES	2	0.87	0.18	< 0.01	0.52	3	7.45	0.06
JHS	13	1.12	0.06	< 0.01	58.14			
SHS	19	0.82	0.07	< 0.01	51.81			
College	8	0.98	0.08	< 0.01	62.28			
Experiment Group Capacity								
≤ 30	14	0.98	0.03	< 0.01	91.06	1	0.29	0.62
> 30	28	0.88	0.63	< 0.01	88.92			
Platforms								
Edmodo	1	1.21	0.25	< 0.01	0.00	6	21.98	0.00
Google Classroom	7	0.71	0.08	< 0.01	23.73			
Khan Academy	4	0.74	0.11	< 0.01	8.48			
Moodle	6	1.06	0.10	< 0.01	17.45			
QQ Learning	1	0.64	0.21	< 0.01	0.00			
WhatsApp	15	1.12	0.05	< 0.01	30.04			
Not Report	8	1.03	0.10	< 0.01	78.52			
Publication Year								
2016-2019	17	0.94	0.06	< 0.01	93.05	1	0.21	0.64
2020-2023	25	0.97	0.05	< 0.01	86.96			
Publcation Type								
Journal	39	0.92	0.04	< 0.01	165.51	1	7.94	0.01
Proceedings	3	1.30	0.13	< 0.01	6.75			

Level of Education

The result of moderator variable analysis regarding education level shows that GFC implementation gives significant influence on mathematic skills of elementary school students ($g = 0.87$; $p = 0.00$), junior high school ($g = 1.12$; $p = 0.00$), high school ($g = 0.82$; $p = 0.00$), and university ($g = 0.98$; $p = 0.00$). The heterogeneity test showed that the average effect size of the four groups did not show a significant difference ($Qb = 7.45$; $p = 0.06$). These results indicate that the education level variable does not affect the impact of GFC use on students' mathematic skills. In other words, the effectiveness of GFC in improving students' mathematic skills remains consistent, whether it is applied at the elementary school level to higher education.

This is also reinforced by research findings which suggest that the technology that is useful and considered effective in learning mathematics is GeoGebra and can be used to teach in elementary schools and even at the university level (Azka, 2024; Hohenwarter et al., 2008; Septian, 2017). This finding is in line with the results of previous studies, such as Wei et al., (2020) and Vitta & Al-Hoorie (2023) which show that the education level variable has no significant influence on the effectiveness of using GFC. An important implication of this finding is that GFC can be considered as an effective strategy to improve students' mathematic skills at various levels of education, including elementary school, junior high school, high school, and university. GeoGebra, as a mathematical software that supports visualization and interactivity, allows students to explore mathematical concepts more deeply (Dahal et al., 2022; Thapa et al., 2022). For example, at the primary and secondary school levels, students can use GeoGebra to understand their knowledge of coordinate systems (Putri et al., 2023), geometry or algebra by drawing and manipulating mathematical objects. At the higher education level, GeoGebra can be used to deepen understanding of calculus or data analysis.

Capacity of the Experimental Group

The results of the moderator variable analysis regarding the capacity of the experimental group showed a significant increase in student mathematic skills through the application of GFC in experimental class capacities d" 30 ($g = 0.98$; $p = 0.00$) and > 30 ($g = 0.88$; $p = 0.00$). The result of heterogeneity test showed the average effect size of both groups showed insignificant difference ($Qb = 0.29$; $p = 0.62$). The result showed that the variable capacity of experimental group did not influence the impact of GFC usage on students' mathematic skills. In other words, the effectiveness of using GFC on students' MATHEMATIC SKILLS is not different based on the type of experimental capacity. Although there was a difference in effect size between the two groups, the heterogeneity analysis showed that this difference was not statistically significant.

This finding is consistent with previous research showing that class size does not significantly affect the effectiveness of the problem-based learning model integrated with flipped classroom in mathematics learning achievement (Sappaile et al., 2020). The research shows that although class sizes vary, both large and small classes, the integration of GeoGebra in a flipped classroom still has a positive impact on students' math skills. In a flipped classroom, students have access to independent learning and utilize technology, such as GeoGebra, to deepen students' understanding (Hidayat et al., 2021; Ishartono et al., 2022). This allows every student, regardless of class size, to interact with the material in a more personalized way. Even in large classes, technology such as GeoGebra can enrich students' learning experience without depending on the physical size of the class, as learning is more individualized and technology-based.

Research conducted by Wati & Sari (2020) showed that despite the challenges of managing a large class, the integration of GeoGebra with a flipped classroom was still able to significantly improve students' math skills. The implication of this finding is that educators can plan and implement GFC in various class sizes without worrying about significant differences in its impact on student mathematic skills. This provides flexibility and opportunity for the use of GFC in various mathematics learning contexts.

The Media Platforms

The results of the moderator variable analysis related to the media platform used in the implementation of GFC showed that the implementation of GFC with the support of certain media platforms had a significant effect on student mathematic skills. The effect is seen in the use of Edmodo platform (g = 1.21; p = 0.00), Google Classroom (g = 0.71; p = 0.00), Khan Academy (g = 0.74; p = 0.00), Moodle (g = 1.06; p = 0.00), QQ Learning (g = 0.64; p = 0.00), and WhatsApp (g = 1.12; p = 0.00). The heterogeneit test results showed a significant difference in mean effect size between the seven groups (Qb = 21.98; p = 0.00). This finding shows that the type of media platform influences the impact of using GFC on students' mathematic skills.

WhatsApp has a greater impact than other platforms when it comes to teaching GeoGebra using the Flipped Classroom approach due to several key factors that encourage student participation, accessibility, and teamwork. As the most widely used instant messaging application, WhatsApp has become a very familiar and easy-to-use communication tool for many users, especially in areas with less than optimal technological infrastructure (Mustar & Nashihuddin, 2020; Yudianto & Murtiyasa, 2021). It allows students to connect with pre-provided learning materials, analyze learning outcomes using GeoGebra and discuss questions or problems informally with teachers and/or peers through text messages, voice notes and video recording.

In addition, WhatsApp facilitates asynchronous and synchronous learning, allowing students to access learning materials immediately and discuss them in real time as needed (Handayani et al., 2022; Hendri, 2022; Melfawani et al., 2022). With a high level of engagement in group discussions, students are more involved in their learning and work together to understand the mathematical concepts taught through GeoGebra. The ease of downloading files and media also enhances learning effectiveness by allowing students to receive feedback silently from their teachers. Therefore, WhatsApp offers flexibility and hands-on learning, making it more effective than other platforms in the context of teaching with GeoGebra through Flipped Classroom.

This result is in accordance with the research of Sappaile et al. (2020) and Sulistyowati et al. (2023) who also found that the GEEn. Despite the significant differences between the media platform groups studied, our research shows that the use of GFC still has a significant impact on all types of media platforms investigated, including Edmodo, Google Classroom, Khan Academy, Moodle, QQ Learning, and WhatsApp. Research shows that the use of this media platform not only accelerates the learning process but also increases student engagement, especially in the mastery of more complex math concepts such as geometry and algebra (T. M. Siregar et al., 2023). In a flipped classroom, students learn the material independently through various resources, such as learning videos that utilize GeoGebra for mathematical visualization, before moving on to face-to-face sessions for discussion or problem solving.

In addition, the diversity of platforms allows flexibility for students to access materials according to their needs, both inside and outside of class hours. This implementation also facilitates a more structured and technology-based learning evaluation, which enhances students' overall understanding. Thus, the integration of GeoGebra and flipped classroom through various media platforms can create a more engaging and effective learning experience. These findings provide evidence that GFC can be implemented effectively using various media platforms. Each media platform has its own role and characteristics in supporting effective mathematics learning, and a deep understanding of the characteristics of each platform can help teachers make the right decisions in implementing GFC.

Although there were no significant differences in the impact of GFC based on education level, experimental group capacity and year of publication, this suggests that GFC can be applied flexibly across different levels and educational contexts without losing its effectiveness. Therefore, this study can provide encouragement for educators and educational policy makers to pay more attention to the application of GFC as part of a holistic and innovative mathematics learning strategy. Although these findings make a valuable contribution to our understanding of the effectiveness of GFC, there are some limitations in this study, including that this study only includes research published in scientific journals, and the limited number of studies (31 primary studies) is considered. Therefore, future research is expected to expand its scope by involving other literature sources, such as master theses and doctoral dissertations, to strengthen and generalize the findings obtained.

Based on the analysis of some findings related to Geogebra integration in Flipped Classroom, it can be stated that the use of GFC is still effectively implemented at any particular level of education. In addition, the number of students also does not limit the significance of GFC in providing meaningful experiences for students. GFC implementation can also be done with various media platforms that still provide the essence of fun learning according to the needs and conditions of students. While GeoGebra can provide benefits in enhancing students' learning experience in a Flipped Classroom, its impact on students' math skills may vary. It is important to consider a variety of factors, including students' technological abilities, the quality of classroom interactions, and the instructional approach used, to ensure the effectiveness of GeoGebra integration in improving students' math skills.

■ CONCLUSION

The implication of this research finding is that GFC can be an effective learning approach in improving students' mathematic skills. This provides empirical support for the use of GFC as an alternative or addition in mathematics learning practices. GeoGebra in a Flipped Classroom context for hybrid learning can be implemented by giving students access to interactive learning materials through video tutorials or GeoGebra-based assignments before class sessions, both online and face-to-face. Students can explore mathematical concepts independently by using GeoGebra's graphical tools, such as drawing function graphs, manipulating geometry, or solving algebraic problems directly. When the face-to-face session begins, either in a physical classroom or through the online platform, time can be spent on more in-depth discussions, collaborative problem solving, and application of concepts learned, with more personalized instruction to suit students' needs.

Although these findings make a valuable contribution to our understanding of the effectiveness of the GFC, there are some limitations in this study, including that this study only includes studies published in scientific journals, and the limited number of studies (31 primary studies) needs to be considered. Therefore, future research is expected to expand its scope by involving other literature sources, such as master's theses and doctoral dissertations, to strengthen and generalize the findings obtained. Recommendations for future research include expanding literature sources and studies to obtain a more comprehensive picture of the effectiveness of the GFC. In addition, the moderator variables analyzed can be expanded to include additional factors, such as sampling techniques, experiment duration, and types of learning materials. This is expected to provide a deeper understanding of the factors that influence the effectiveness of GFC in the context of mathematics learning.

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