Meta-Analysis : The Influence of the Game Based Learning (GBL) Model On Students' Mathematics Learning Outcomes

Ade Dwi Oktaviani[1*)], Meiliasari[2], Wardani Rahayu[3], Makmuri[4,] Tian Abdul Aziz[5]
[1,2,3,4,5]Universitas Negeri Jakarta
*) oadedwi@gmail.com

Abstract

Mathematics learning outcomes remain a challenge across various educational levels, highlighting the need for instructional approaches that enhance student engagement and understanding. One of the widely implemented approaches is *Game Based Learning* (GBL). This study aimed to examine the overall effect of GBL on students' mathematics learning outcomes and to identify differences in effect sizes based on game type, sample size, and educational level through a meta-analysis approach. The study employed a meta-analysis method following the PRISMA guidelines. A total of 25 primary studies published between 2019 and 2026 that met the inclusion criteria were analyzed using JASP software. Effect sizes were calculated using Hedges' g and synthesized through a random-effects model. The results revealed that GBL had a very large positive effect on mathematics learning outcomes, with a pooled effect size of 2.184 (95% CI [1.101, 3.268]; $p < 0.001$). Heterogeneity analysis indicated substantial variation among studies ($Q = 1129.72$; $I^2 = 98.89\%$), leading to moderator analyses. The findings showed that game type ($F = 0.1125$; $p = 0.740$) and sample size ($F = 0.073$; $p = 0.930$) were not significant moderators of effect size variation. In contrast, educational level was found to be a significant moderator ($F = 4.563$; $p = 0.009$), with the largest effect size observed at the higher education level ($g = 10.630$). Publication bias analyses using Funnel Plot, Fail-Safe N (9076), and Trim and Fill indicated that the meta-analytic findings were highly robust and minimally affected by publication bias. These findings suggest that Game Based Learning is an effective instructional approach for improving students' mathematics learning outcomes across different educational levels..

Keywords: Game Based Learning, mathematics learning outcomes, meta-analysis, effect size, moderator analysis.

Introduction

Mathematics learning outcomes are one of the important indicators in assessing the success of the learning process because it reflects the level of mastery of concepts, skills, and the ability of students to apply the knowledge that has been learned. In mathematics learning, learning outcomes are not only shown through the ability to do calculations, but also through understanding concepts, reasoning, problem solving, and the ability to apply mathematical concepts in various situations. According to NCTM (2000), mathematics learning must be able to develop problem-solving, reasoning, communication, connection, and mathematical representation skills as part of student learning success. However, students' mathematics learning outcomes are still a problem at various levels of education.

This condition is reflected in the results *Programme for International Student Assessment* (PISA) in 2022 which shows that the mathematics score of Indonesian students is 366, still below the OECD average of 472 (PISA, 2022). These findings indicate that most students still have difficulty in understanding, applying, and reasoning mathematical concepts in various problem contexts. In addition, low mathematics learning outcomes can be influenced by various factors, one of which is the use of a learning model that is still teacher-centered so that students are less actively involved in the learning process (Squirrel & Hartanto, 2017). In line with opinion Juliante (2018), learning that is dominated by lecture methods tends to cause students to be less interested, less motivated, and have difficulty understanding abstract mathematical concepts. Therefore, a learning model that is able to create an active, fun, and student-centered learning atmosphere is needed so that mathematics learning outcomes can improve. One of the learning models that can be used is *Game Based Learning* (GBL). *Game Based Learning* is a learning approach that utilizes games as a means to achieve learning goals (Islam et al. 2024). According to Fatmawati and Siregar (2026) Through game activities, students not only gain a fun learning experience, but also actively engage in the process of thinking, problem solving, decision-making, and social interaction during learning. Various studies show that the use of the GBL model is able to increase student motivation, engagement, and learning achievement because learning becomes more interesting and interactive (Ahmad and Khan 2024). This is in line with the opinion said by the Anggraeni, Herlambang, and Afirianto (2017) that the application *Game Based Learning* can increase student motivation and learning outcomes because learning takes place more interesting and interactive. In addition, the GBL model is also able to increase students' motivation, interest, engagement, and positive attitudes towards mathematics learning. Other research has also shown that math games, both digital-based and non-digital, are able to help students understand math concepts more effectively and improve their learning outcomes (Erşen, Ergül, and Trends 2022).

Despite various studies on the influence of *Game Based Learning* A lot has been done on students' mathematics learning outcomes, the results of the study still show the size of the effect (*effect size*) that are diverse (Tokac, Novak, and Thompson 2019). This variation in effect sizes indicates that the effectiveness of GBL has not shown consistent results across studies, which may be attributable to differences in study characteristics such as education level, sample size, type of game, research context, and type of publication. Therefore, a study that is able to integrate the results of these studies quantitatively is needed to obtain a more comprehensive picture of the influence of *Game Based Learning* (GBL) on students' mathematics learning outcomes (Makarim and Fathurrohman 2023). One approach that can be used to obtain more comprehensive conclusions from the various research results is meta-analysis.

Meta analysis is a research method that can be used to combine and analyze the results of various relevant studies so that more accurate and comprehensive conclusions are obtained (Fatah et al. 2025). According to Retnawati et al. (2018) Meta analysis is used to summarize, integrate, and interpret the results of quantitatively relevant studies. Through meta-analysis, the effect measures from various studies can be calculated and integrated so that the magnitude of the influence of a treatment as a whole can be known. Unlike previous studies that generally only reviewed the effectiveness of GBL in general, this study also analyzed differences in effect sizes based on the type of game used in mathematics learning. The analysis is important to provide information about the type of game that has the most potential to improve students' mathematics learning outcomes.

Based on this description, this study aims to examine the influence of the model *Game Based Learning* (GBL) on students' mathematics learning outcomes through a meta-analysis approach and identifying differences in effect sizes based on game type, sample size, and level of education used in mathematics learning. The results of this study are expected to provide an empirical basis for educators in choosing and implementing effective game types to improve students' mathematics learning outcomes.

Method

This study uses a meta-analysis method to integrate the results of research on the influence of *Game Based Learning* (GBL) on students' mathematics learning outcomes. Meta-analysis is a quantitative research method used to combine and analyze the results of various primary studies so that a more accurate and comprehensive estimate of influence is obtained (Retnawati et al. 2018).

Eligibility Criteria (PICOS)

The inclusion criteria in this study are compiled based on the PICOS framework (*Population, Intervention, Comparison, Outcomes, Study Design*) used to determine the feasibility of the primary study being analysed (Nursalam, 2020). The inclusion criteria used include: (1) primary studies involving students at the elementary/equivalent, junior high/equivalent, high school/equivalent, or university levels; (2) using Game Based Learning (GBL) as a treatment in the experimental group; (3) using conventional learning or other learning models as a comparison group; (4) measuring mathematics learning outcomes as outcome variables (*outcome*); (5) using experimental or quasi-experimental research designs with experimental groups and control groups; (6) provide the necessary statistical data for calculation *effect size*, such as the number of samples, the average (*mean*), and standard deviation; (7) published in the range of 2019–2026; and (8) available in the form of a fully accessible journal article (*full text*). Studies that did not meet these criteria, used a non-experimental design, or did not provide the necessary statistical data were not included in the meta-analysis.

Literature Search Strategy

The process of identification, screening, and selection of primary studies is carried out with reference to the guidelines *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA) (Liberati et al. 2009). The research stages include determining inclusion and exclusion criteria, searching and selecting primary studies, extracting and coding data, calculating effect sizes (*effect size*), and statistical analysis using JASP software (Tokac et al. 2019).

The literature search was conducted in accordance with the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA) guidelines using *Google Scholar, ScienceDirect,* and *Semantic Scholar.* Full-text articles that were unavailable through these databases were retrieved from *ResearchGate* whenever accessible. The search employed keywords related to *Game-Based Learning* (GBL) and mathematics learning. These sources were selected because they provide broad access to educational research relevant to the objectives of this study. To ensure a comprehensive and transparent literature selection process, duplicate records were removed and predefined inclusion and exclusion criteria were applied systematically.

Study Selection (PRISMA)

The search keywords were developed based on the research objectives, core variables, and relevant terms reported in previous studies. Preliminary searches were conducted to refine the keywords, and Boolean operators (AND/OR) were applied to improve the relevance of the search results. The search identified 350 records, and after duplicate removal and screening based on the predefined eligibility criteria, 25 primary studies were included in the final meta-analysis. The study selection process is presented in the PRISMA flow diagram (Figure 1).

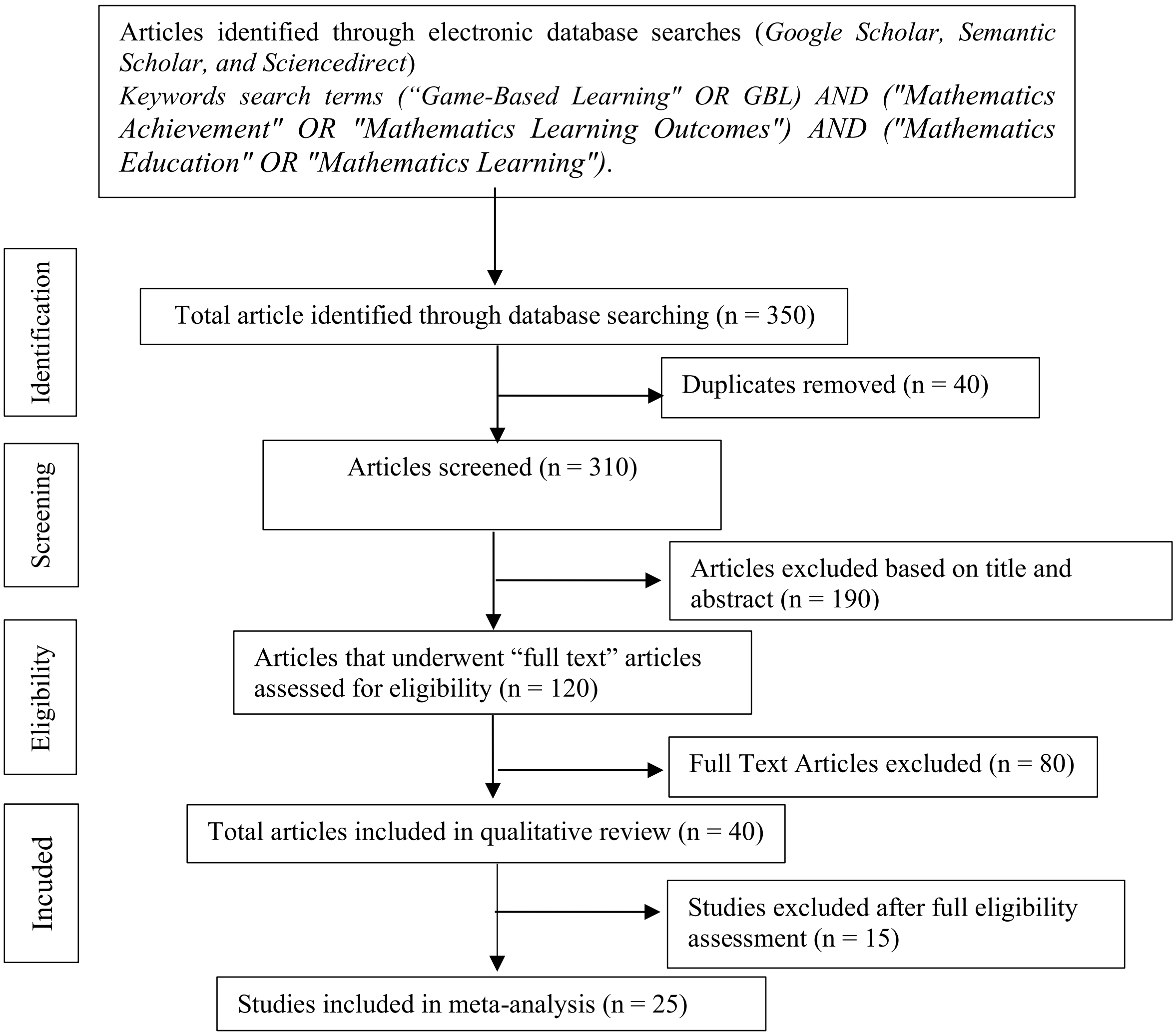

Figure 1. PRISMA Diagram Meta-Analysis Stages

Data Extraction

Articles that meet the inclusion criteria are then extracted using a coding sheet (*coding sheet*) compiled in Microsoft Excel. The data extraction process is carried out systematically to collect the information required in the meta-analysis analysis. The data extracted included the author's name, year of publication, country of research, level of education, type of game used, number of samples of experimental and control groups, average score (*red*), standard deviation (SD), as well as other statistical information required to calculate *effect size*. In addition, the characteristics of the study used as moderator variables were also recorded in the data coding process. To minimize coding errors, all extracted data were double-checked by matching the information listed in each primary study before statistical analysis was performed.

Statistical Analysis

The extracted data is then analyzed using JASP software. Effect size (*effect size*) used in this study are *Hedges' g* because it is able to correct for bias in relatively small sample sizes. Value *effect size* obtained from each primary study was then integrated to obtain an estimate of the influence of the GBL model on students' overall mathematics learning outcomes. The interpretation of effect size refers to the criteria of Cohen (1988) presented in Table 1.

Table 1. Effect Size Criteria

Interval	Criteria
$ES < 0.20$	Very Small
$0.20 \leq IS \leq 0.49$	Small
$0.50 \leq IS \leq 0.79$	Medium
$ES \geq 0.80$	Large

Source: (Lakens, 2013).

Before synthesizing the results, a heterogeneity test was first carried out using Q statistics and I^2 index to determine the degree of variation in effect size between primary studies (Higgins et al., 2003). If the results of the heterogeneity test show a p < value of 0.05 and a high I^2 index, then it is used *Random Effects Model*. Conversely, if the heterogeneity between studies is low, it is used *Fixed Effect Model*

Furthermore, the publication bias test was carried out using *Funnel Plot, Fail-Safe N* (FSN), and *Trim and Fill* to identify possible publication bias in the primary studies analyzed. In addition, the moderator's analysis was conducted based on the type of game, sample size, and level of education used in mathematics learning to identify differences in effect sizes between study groups. The results of all these analyses are used to explain the magnitude of the influence of the model *Game Based Learning* to students' mathematics learning outcomes and their variations based on the characteristics of the study being studied.

Results and Discussion

This study used 25 primary studies that met the inclusion criteria and were included in the meta-analysis. The studies were published in the range of 2019–2026 and examined the influence of *Game Based Learning* (GBL) on the mathematics learning outcomes of students at various levels of education, ranging from elementary school to college. The primary studies analyzed came from different countries and used different types of games in the mathematics learning process. The data *Extracted* of each study including the number of samples of the experimental and control groups, the mean value (*mean*), standard deviation (*standard deviation*), as well as other statistical information required in the calculation *effect size*.

Research Results

A summary of the characteristics and results of primary study data extraction is presented in Table 2.

Table 2. Results of Statistical Data Extraction

No	Model GBL				Model Convensional			T value	P value
	Citation	Xe	Vehicles	Sde	Nc	Xc	Sdc		
1	Sulmiati (2022)	20	73.95	2.53	20	79.10	2.72	3.279	0.000
2	Dhuha et al. (2024)	28	85.07	9.25	28	71.39	8.25	3.408	0.006
3	Wardani et al. (2024)	21	77.90	2.53	21	72.14	2.72	-5.107	0.000
4	Rosyida and Sutriyani (2026)	23	70.90	9.25	21	53.80	10.48	5.376	0.001
5	Squirting (2025)	29	85.07	8.48	29	71.39	12.88	-8.794	0.000
6	Asyakur et al. (2026)	28	86.57	10.28	28	73.21	5.97	3.279	0.001
7	Nurjiah and Marna (2025)	36	87.19	11.49	36	41.28	20.15	-13.209	0.000
8	Ully and Dewi (2022)	34	81.32	10.28	34	74.63	5.97	3.279	0.000
9	Kudri and Maisharoh (2021)	30	81.83	1.37	30	66.67	1.45	4.950	0.000
10	Ihsan et al. (2024)	22	91.30	6.33	23	66.23	8.26	17.288	0.000
11	Nurul et al. (2023)	32	9.25	0.93	32	5.94	2.49	4.92	0.001
12	Mansureh et al. (2020)	117	45.71	17.55	76	32.00	13.65	6.928	0.009
13	Rahim et al. (2025)	27	25.52	1.74	27	14.59	2.17	20.406	0.001
14	Sumale et al. (2024)	25	74.68	1.39	25	61.88	1.35	48.05	0.001
15	Bringula et al. (2025)	55	8.85	2.06	64	9.34	2.28	5.471	0.000
16	Iwen and Hwang (2014)	46	92.09	9.66	23	87.22	7.47	4.710	0.001
17	Pan et al. (2025)	56	33.93	9.27	29	14.66	6.06	6.660	0.001
18	Fransisco (2020)	25	5.76	1.54	22	5.22	2.49	-7.884	0.000
19	Fadillah et al. (2025)	20	84.75	11.96	20	70.25	10.93	4.323	0.001
20	Dorji and Rigdel (2024)	31	8.74	2.86	31	5.87	3.06	6.230	0.000
21	Brezovszky et al. (2019)	642	79.48	19.85	526	15.54	4.41	13.370	0.000
22	Supriadi et al. (2020)	32	84.94	10.33	32	70.74	11.79	6.235	0.000
23	Rahmania et al. (2024)	25	88.60	7.00	25	68.80	9.61	3.380	0.000
24	Ananda and Nalim (2024)	37	74.76	6.33	35	57.71	8.26	-16.487	0.000
25	Rahimi et al. (2022)	46	10.17	2.51	53	9.11	2.89	5.469	0.000

Based on the characteristics of the studies presented in Table 2, it can be seen that there are variations in mean values, standard deviations, and sample sizes in each study. Extraction data obtained from 25 primary studies were then analyzed using meta-analysis techniques to determine the overall effect *Game Based Learning* (GBL) on students' mathematics learning outcomes. The analysis is carried out by combining *effect size* from each study so that a more comprehensive estimate of the influence was obtained than the results of individual research. The results of the meta analysis using the random effects model are presented in Table 3.

Table 3. Summary of Estimated *Effect size* and Heterogeneity of the Influence *of Game Based Learning* on Students' Mathematics Learning Outcomes

Parameter	**Value**
Number of Studies	25
Effect size (Hedges' g)	2,184
Standard Error	0,525
95% CI Lower	1,101
95% CI Upper	3,268
Q	1129,72
p-value	<0.001
t	2,498
t^2	6,242
I^2	98,89%

Source : Results of meta-analysis using JASP

The results of the meta-analysis presented in Table 3 show that *effect size* combined (*Hedges' g*) the effect of GBL on students' mathematics learning outcomes was 2.184 with a standard error of 0.525. The value is in a 95% confidence interval between 1,101 and 3,268. Based on Cohen's criteria, the *effect size* that exceeds 0.80 is included in the large category. Thus, *effect size* of 2,184 shows that the implementation of GBL has a very large positive influence on students' mathematics learning outcomes compared to conventional learning. In addition, the results of the significance test showed a p value of $p < 0.001$, so it can be concluded that the influence of GBL on students' mathematics learning outcomes is statistically significant. These findings show that the use of GBL is one of the effective learning alternatives in improving students' mathematics learning outcomes.

Although obtained *effect size* The combination of high, heterogeneity test results showed a variation in influence between the studies analyzed. This is indicated by a Q value of 1129.72 with $p < 0.001$ indicating that *effect size* The results of each study are not homogeneous. The findings were corroborated by an I^2 value of 98.89%, which suggests that most of the variation *effect size* The differences in the characteristics of the studies analysed came from differences in the characteristics of the studies. Based on criteria Higgins et al. (2003) I^2 values above 75% fall into the category of high heterogeneity. This high heterogeneity indicates that there are certain factors that have the potential to affect the variation in the influence of GBL on students' mathematics learning outcomes. Therefore, a moderator analysis was conducted to identify the characteristics of the study that contributed to the differences *effect size* between research. In this study, the moderators analyzed included game type, sample size, and education level.

To identify the source of heterogeneity between studies, a moderator analysis was conducted. Moderator analysis was performed to identify the source of variation *effect size* between studies. The moderator variables analyzed included game type, sample size, and education level. Game types are categorized into digital and non-digital based on the characteristics of the gaming media used in each study. Sample sizes were grouped into small, medium, and large categories based on the quartile distribution of the total study sample analyzed. Meanwhile, the level of education is classified according to the level of education of students reported in the primary study, namely elementary, junior high, high school, vocational school and college. The categories of each moderator are arranged based on the characteristics of the study analyzed and presented in Table 4

Table 4. Characteristics of Moderator Studies

Moderator	Category	Criteria
Game Type	Digital	Using digital devices (computers, smartphones, web, apps)
	Non-Digital	Using physical media without digital devices
Sample Size	Small	≤ 48 participants
	Medium	49–72 participants
	Large	> 72 participants
Education Level	SD	Elementary School/equivalent
	Junior High School	Junior High School/equivalent
	High School	High School/equivalent
	SMK	Vocational High School
	College	Students

Once the moderator grouping process is underway, the next stage is to test whether differences in study characteristics contribute to variation *effect size* found. The moderator's analysis was carried out based on the type of game, sample size, and level of education used in the implementation of Game Based Learning.

1. Moderator Analysis by Game Type

In this study, the types of games are grouped into two categories, namely *digital game* and *non-digital game*. The moderator's analysis was conducted to find out whether differences in game types resulted in different influences on students' math learning outcomes. The results of the moderator's analysis based on game type are presented in Table 5 and Table 6.

Table 5. Moderator Test Results by Game Type

Predictor	F	df_1	df_2	p
Game Type	0,1125	1	23	0,740

Source : Analysis results using JASP

Based on Table 5, the results of the meta-regression test showed that the game type did not have a significant effect on the variation *effect size* obtained ($F(1.23) = 0.1125$; $p = 0.740$). A p-value greater than 0.05 indicates that the game type is not a significant moderator of the influence *Game Based Learning* on students' mathematics learning outcomes.

Table 6. Moderator Analysis Results by Game Type

Game Type	Number of Studies	*Effect size* (g)	SE	95% CI
Digital	15	2,254	0,572	[1,072 ; 3,437]
Non-Digital	10	1,704	1,540	[-1,483 ; 4,890]

Source : Results using JASP

Based on Table 6, the *digital game* Acquire *effect size* 2,254, while the *non-digital game* Acquire *effect size* by 1,704. Descriptively, *digital game* show *effect size* higher than non-digital games. However, the difference was not statistically significant as shown in the previous moderator test results. These findings indicate that game type is not the main factor explaining variation *effect size* between research. In other words, both digital and non-digital games have relatively equal potential in improving students' mathematics learning outcomes.

These findings are in line with constructivist theory which emphasizes that learners actively build their knowledge through learning experiences and interactions during the learning process (Do, Do, and Nguyen 2023). In the context of GBL, both digital and non-digital games can provide opportunities for students to explore concepts, solve problems, and actively build understanding. Therefore, the effectiveness of GBL is determined more by how the game activities are designed and integrated into learning than by the type of game used.

2. Moderator Analysis Based on Sample Size

The sample size was categorized into three groups, namely small, medium, and large. Moderator analysis was conducted to find out whether differences in sample size resulted in variations in influence *Game Based Learning* on students' mathematics learning outcomes. The results of the moderator's analysis based on sample size are presented in table 7 and table 8.

Table 7. Moderator Test Results Based on Sample Size

Predictor	F	df_1	df_2	p
Sample Size	0,073	2	22	0,930

Source : JASP Analysis Results

Based on Table 7, the results of the meta-regression test showed that the sample size did not have a significant effect on the effect *size* variation obtained. This is shown by the value F(2.22) = 0.073 with p = 0.930. Because the p-value is greater than 0.05, the sample size cannot be stated as a significant moderator in explaining the difference in the influence of GBL on students' mathematics learning outcomes. Thus, the difference in the number of study participants did not contribute significantly to the variation *in effect size* between studies.

Table 8. *Effect size* Based on Sample Size

Sample Size	*Effect size* (g)	OR	95% CI
Large	1,629	1,568	[-1,622 ; 4,880]
Small	2,273	0,794	[0,626 ; 3,919]
Medium	2,266	0,867	[0,468 ; 4,064]

Source : JASP Analysis Results

In Table 8, studies with a small sample size obtained *effect size* of 2,273, while the study with a moderate sample size obtained *effect size* by 2,266. The research with a large sample size obtained *effect size* by 1,629. Descriptively, studies with small and medium sample sizes show *effect size* higher than studies with large sample sizes. However, based on the results of the moderator test in Table 6, the difference is not statistically significant so the sample size cannot be stated as a factor affecting the variation *effect size* between research. The insignificance of the influence of sample size suggests that variation in the number of study participants is not the main factor explaining the difference *effect size* between studies. This shows that the effectiveness of GBL on students' mathematics learning outcomes tends to be consistent across different sizes of the research sample. Thus, the success of the implementation of GBL was influenced more by the quality of the learning implementation, the characteristics of the students, and the design of the game activities than by the number of participants involved in the study.

3. Moderator Analysis Based on Education Level

Moderator analysis based on education level was used to find out whether the influence of GBL on mathematics learning outcomes differs at each level of education. The results of the moderator's analysis are presented in Table 9 and Table 10.

Table 9. Moderator Test Results Based on Education Level

Predictor	**F**	**df_1**	**df_2**	**p**
Education Level	4,563	4	20	0,009

Source : JASP Analysis Results

Based on Table 9, the results of the meta-regression test show that the level of education has a significant effect on the variation *in effect size* obtained. This is indicated by the value of $F(4.20) = 4.563$ with $p = 0.009$. Because the p value is less than 0.05, the level of education can be stated as a significant moderator in explaining the difference in the influence of GBL on students' mathematics learning outcomes. Thus, the effectiveness of GBL in improving mathematics learning outcomes differs at each level of education.

Table 10. *Effect size* Based on Education Level

Jenjang	***Effect size* (g)**	**SE**	**95% CI**
College	10,630	2,245	[5,951 ; 15,320]
SMA	3,513	1,030	[1,365 ; 5,660]
SD	1,747	0,610	[0,475 ; 3,020]
SMP	1,331	0,713	[-0,157 ; 2,818]
SMK	0,787	2,009	[-3,403 ; 4,977]

Source : JASP Analysis Results

Based on Table 10, the group of universities obtained *effect size* the highest number of 10,630, followed by high school at 3,513, elementary school at 1,747, junior high school at 1,331, and vocational school at 0.787. These results show that the influence of GBL on mathematics learning outcomes is different at each level of education. The college group shows *effect size* highest in the studies analyzed.

The significance of the influence of the level of education shows that the characteristics of students at each level of education contribute to the effectiveness of GBL. The differences in cognitive abilities, the level of learning independence, experience using technology, and the complexity of the mathematics materials studied allow each level of education to respond differently to the implementation of GBL. In line with Piaget's theory of cognitive development, which explains that individuals at the formal operational stage have more complex abstract thinking skills, hypothetical reasoning, and problem-solving than the previous developmental stages. This ability allows students at a higher level of education to utilize game activities as a means of exploring mathematical concepts in a more in-depth and reflective manner (Pakpahan et al. 2022).

In addition, students at higher levels of education generally have abstract thinking skills, learning independence, and more developed learning experiences than students at lower levels. These conditions allow them to be more optimal in understanding the rules of the game, completing the challenges given, and connecting the game activities with the mathematical concepts they learned. These findings show that student characteristics are a more influential factor in explaining variation *effect size* compared to the type of game and the size of the research sample. Thus, the success of the implementation of GBL is not only determined by the use of games in learning, but also by the suitability of learning design with the characteristics and needs of students at each level of education.

To assess the validity and stability of the meta-analysis results, a publication bias test was conducted on the primary studies analyzed. The publication bias test aims to identify possible publication biases that may affect estimates *effect size* combined. In this study, the publication bias test was carried out using *Funnel Plot, Fail-Safe N (FSN)*, and the *Trim and Fill*. The results of the test were used to evaluate whether the results of the meta-analysis obtained were robust enough and avoided the influence of publication bias.

A. Funnel Plot

Funnel Plot is one of the most commonly used methods to detect possible publication bias in meta-analysis studies. This graph shows the relationship between *effect size* on the horizontal axis and standard error on the vertical axis. Theoretically, if there is no publication bias, then the research points will be spread symmetrically to form a funnel-like pattern (*Funnel*) around the value *effect size* combined. Conversely, asymmetrical point distribution patterns may indicate possible publication bias or characteristic variation between the studies analyzed (Sterne et al. 2011). The results of the analysis using Funnel Plot are presented in Figure 2.

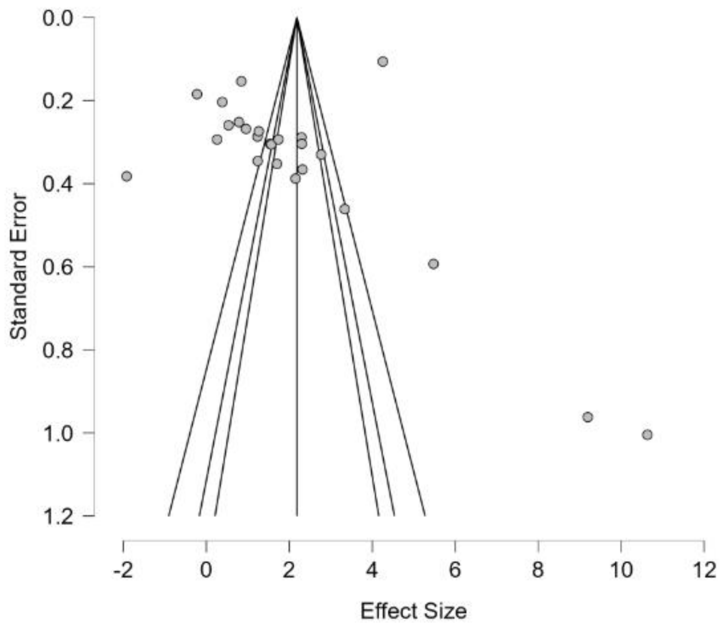

Figure 2. Funnel Plot The Influence of GBL on Students' Mathematics Learning Outcomes

Based on Figure 2, the distribution of the study points does not show a completely symmetrical pattern around the line *effect size* combined. Most studies concentrated on the middle area with a score of *effect size* positive, but there are several studies that have *effect size* relatively high so it is on the right side of the chart. This condition causes the dot distribution pattern to appear less symmetrical. Nonetheless, the asymmetry of the Plot Funnel does not necessarily indicate the existence of publication bias. In this study, a very high heterogeneity value ($I^2 = 98.89\%$) showed a large variation in characteristics between studies, so that the shape of the Funnel Plot could be influenced by the differences in the characteristics of the analyzed study.

The result of the Funnel Plot parameter estimation shows the value of *effect size* Combined (μ) of 2.184 with a 95% confidence interval between 1.192 to 3.177 ($p < 0.001$). In addition, a τ value of 2.498 was obtained with a 95% confidence interval between 1.969 to 3.705 ($p < 0.001$). These results show that the influence of Game Based Learning on students' mathematics learning outcomes remains significant, despite variations *effect size* which is quite large between studies. Therefore, a follow-up analysis was carried out using the *Fail-Safe N* to obtain a more comprehensive evaluation of the possibility of publication bias.

B. Fail-Safe N (FSN)

Fail-Safe N (FSN) is a method used to evaluate the resilience of meta-analysis results to the possibility of unpublished studies. This method estimates the number of additional studies required to convert significant meta-analysis results into insignificant. The greater the FSN value obtained, the stronger and more stable the meta-analysis results against possible publication bias (Borenstein et al. 2009). The results of the analysis using Funnel Plot are presented in Table 11.

Table 11. *Fail-Safe N* (FSN) test results

Parameter	Value
Number of Studies (k)	25
Rosenthal Fail-Safe N	9076
Criteria (5k + 10)	135
Verdict	There is no indication of significant publication bias

Source : JASP Analysis Results

Based on Table 11, the Rosenthal Fail-Safe value of N is 9076. These values suggest that approximately 9076 additional studies with insignificant outcomes are needed to convert significant meta-analysis results into insignificant. Based on criteria Rosenthal (1979) The results of the meta-analysis can be considered to have adequate resistance to the possibility of unpublished studies if the Fail-Safe value of N exceeds the value of 5K+10, with K being the number of studies analyzed. In this study, an FSN value of 9076 was obtained, far exceeding the minimum limit of 135, so that the results of the meta-analysis can be stated to have a very high level of stability.

These results show that the influence of GBL on students' mathematics learning outcomes has a high level of reliability despite the possibility of unpublished studies. However, follow-up analysis using the Trim and Fill method is still carried out to identify the possibility of missing studies and evaluate their effect on the estimation *effect size* obtained combination.

C. Trim and Fill

The *Trim and Fill* method is used to identify the possibility of missing studies due to publication bias and to estimate their influence on the results of the meta-analysis. This method works by detecting asymmetrical asymmetry in *the Funnel Plot*, then estimating the number of missing studies and adding them hypothetically to produce a more symmetrical distribution. Through this procedure, it can be known whether the estimated combined *effect size* has undergone significant changes after corrections are made to possible publication bias (Duval & Tweedie, 2000). The results of the Trim and Fill analysis in this study are presented in Figure 3.

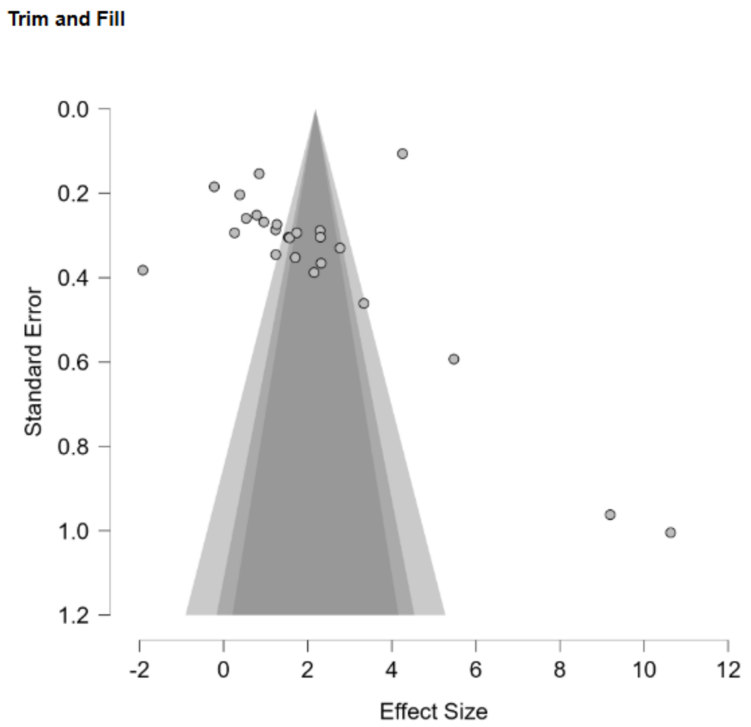

Figure 3. Trim *and Fill Analysis Results*

Based on Figure 3, each point on the graph represents one primary study analyzed in this study. The position of the point on the horizontal axis indicates its magnitude *effect size*, while the position of the point on the vertical axis shows the standard error value of each study. In general, most research is concentrated on the range *effect size* positive, which shows that the majority of studies report a positive influence of Game Based Learning on students' math learning outcomes. In addition, the results of the Trim and Fill analysis do not show any additional points (imputed studies) that need to be added to balance the distribution of the graph. These findings indicate that there are no studies that are expected to be missing due to publication bias that could significantly affect the results of the meta-analysis. Thus, the estimate *effect size* The obtained compound remains stable after evaluation using the Trim and Fill method.

The results were in line with the Fail-Safe N test which resulted in a score of 9076, well above the recommended minimum limit of 135 (5k + 10). Consistency of results between *Funnel Plot, Fail-Safe N,* and *Trim and Fill* shows that the influence of Game Based Learning on students' mathematics learning outcomes obtained in this study has a high level of reliability and is relatively not influenced by publication bias. Therefore, the results of this meta-analysis have a high level of reliability and are relatively not influenced by publication bias, so that the conclusion regarding the effectiveness of GBL on students' mathematics learning outcomes can be trusted.

Discussion of Research Findings

The meta-analysis results demonstrated that *Game-Based Learning* (GBL) had a very large positive effect on students' mathematics learning outcomes, with a combined effect size (Hedges' g) of 2.184. This finding indicates that students who learned through GBL achieved significantly better mathematics learning outcomes than those who experienced conventional instruction. These results are consistent with the meta-analysis conducted by Tokac et al.(2019), which reported that GBL has a significant positive impact on mathematics achievement across various educational settings. Likewise, Singh (2025)argued that integrating game elements into learning enhances students' engagement, motivation, and active participation, leading to improved academic achievement. Therefore, the present findings reinforce previous evidence that GBL is an effective instructional approach for improving mathematics learning outcomes.

The effectiveness of GBL can be explained through constructivist learning theory, which emphasizes that learners actively construct knowledge through exploration, interaction, and problem-solving activities. Unlike teacher-centered instruction, GBL provides students with meaningful learning experiences by incorporating challenges, immediate feedback, and opportunities for collaboration. These learning characteristics encourage both cognitive and emotional engagement, enabling students to understand mathematical concepts more deeply. This interpretation is supported by Palmer (2005), who reported that constructivist learning environments promote higher learning motivation, better learning strategies, and deeper conceptual understanding. Consequently, the interactive nature of GBL creates a learning environment that facilitates meaningful mathematical learning.

Although the overall effect of GBL was very large, the heterogeneity analysis revealed substantial variation among the included studies. The high heterogeneity indicates that the effectiveness of GBL differs across educational contexts and study characteristics. Therefore, moderator analyses were conducted to identify factors contributing to the observed variation in effect sizes.

The moderator analysis showed that game type was not a significant moderator of the effect size. Although digital games produced a descriptively larger effect size than non-digital games, the difference was not statistically significant. This finding suggests that the effectiveness of GBL is determined more by instructional design than by the technological format of the game itself. Both digital and non-digital games can effectively improve mathematics learning outcomes when they actively engage students, provide appropriate challenges, and encourage problem-solving. This finding is consistent with Tokac et al. (2019), who concluded that the educational value of GBL depends primarily on the quality of learning activities rather than on the technology used to deliver them.

Similarly, sample size was not found to be a significant moderator. Although studies with small and medium sample sizes produced slightly larger effect sizes than studies with large sample sizes, these differences were not statistically significant. This result suggests that the effectiveness of GBL is relatively consistent across studies with different participant numbers. Consequently, improvements in mathematics learning outcomes appear to be influenced more by the quality of GBL implementation and student engagement than by the number of participants included in a study.

Unlike the previous moderators, educational level significantly influenced the effectiveness of GBL. The largest effect size was observed among higher education students, followed by senior high school, elementary school, junior high school, and vocational school students. This finding indicates that learner characteristics play an important role in determining the effectiveness of GBL. According to Piaget's theory of cognitive development, students at higher educational levels generally possess more advanced abstract reasoning and problem-solving abilities, allowing them to benefit more from learning activities that require exploration and strategic thinking. This interpretation is supported by Mcleod (2025), who explained that learners in the formal operational stage are better able to process abstract concepts and complex reasoning. Therefore, the implementation of GBL should consider students' developmental characteristics to maximize its effectiveness across different educational levels.

To evaluate the robustness of the meta-analysis, publication bias was assessed using *Funnel Plot, Fail-Safe N* (FSN), and *Trim and Fill* analyses. The Funnel Plot showed no substantial asymmetry attributable to publication bias, while the FSN value of 9076 greatly exceeded the recommended minimum threshold. In addition, the Trim and Fill procedure did not identify any missing studies requiring adjustment. According to Albertine (2016), a large FSN value indicates that meta-analysis findings are highly resistant to the influence of unpublished studies. The consistency of these three publication bias analyses demonstrates that the findings of the present study are robust and provides strong evidence that the positive effect of GBL on mathematics learning outcomes is reliable.

Limitations of The Research

This study has several limitations that need to be considered in interpreting the research results. First, the number of primary studies analyzed is still limited to 25 studies, so it does not fully represent all research on Game Based Learning in mathematics learning. Second, this study is limited to moderator analysis based on game type, sample size, and education level in accordance with the research objectives that have been set. Thus, the interpretation of the research results is focused on these three characteristics so that it does not include all factors that may affect the effectiveness of Game Based Learning on students' mathematics learning outcomes. Third, the high heterogeneity found indicates that there are still other factors that have not been identified and can be a source of effect *size* variation between studies. Therefore, further meta-analysis research is recommended to involve a greater number of studies and consider additional moderators in order to gain a more comprehensive understanding of the effectiveness of GBL in mathematics learning.

Conclusion and Suggestion

The results of the meta-analysis of 25 primary studies showed that GBL had a very large positive influence on students' mathematics learning outcomes with a combined effect size (*Hedges' g*) of 2.184. These findings indicate that the application of GBL is effective in improving mathematics learning outcomes compared to conventional learning. The results of the heterogeneity test showed that there was a high variation in influence between studies, so that moderator analysis was carried out based on game type, sample size, and level of education. The moderator analysis showed that the type of game and sample size had no significant effect on the variation in *effect size*, while the level of education proved to be a significant moderator. The group of universities obtained the highest effect size compared to other levels of education. In addition, the results of publication bias tests using *Funnel Plot, Fail-Safe N*, and *Trim and Fill* showed that the results of the meta-analysis had a high level of reliability and were relatively unaffected by publication bias. Therefore, *Game Based Learning* can be considered as one of the effective learning alternatives to improve students' mathematics learning outcomes at various levels of education.

References

Ahmad, Mubashir, and Raj Wali Khan. 2024. "Gamification in Education : Enhancing the Students Engagement and Learning Achievements through the Integration Use of Game Based Learning." *The Knowledge* 3(1):23–37. doi: 10.63062/tk/2k24a.31016.

Albertine, April. 2016. "Some Methods for Addressing Publication Bias in Statistical." *Thailand Statistician* 14(1):15–24.

Ananda, Kemuning Tria, and Nalim. 2024. "Pengaruh Metode Pembelajaran Game Based Learning Terhadap Hasil Belajar Siswa MAN 1 Brebes." 366–73.

Anggraeni, Dwi, Admaja Dwi Herlambang, and Tri Afirianto. 2017. "Pengaruh Game-Based Learning Terhadap Motivasi Dan Hasil Belajar Peserta Didik Pada Mata Kuliah Pemrograman Dasar." 1(1):1–7.

Ardilla, Ayu, and Suryo Hartanto. 2017. "Faktor Yang Mempengaruhi Rendahnya Hasil Belajar Matematika Siswa Mts Iskandar Muda Batam." 6(2):175–86.

Asyakur, Agus Syarif, Alexxa Tri Fatmasari, and Rima Rahmawati. 2026. "Pengaruh Game Balap Karung Matematika Terhadap Motivasi Dan Hasil Belajar Pecahan Siswa Kelas V." *Pendidikan Dasar* 1(1):14–28.

Borenstein, Michael, L. V Hedges, J. P. T. Higgins, and H. R. Rothstein. 2009. *Introduction to Meta-Analysis*.

Brezovszky, Boglárka, Jake McMullen, Koen Veermans, Minna M. Hannula-Sormunen, Gabriela Rodríguez-Aflecht, Nonmanut Pongsakdi, Eero Laakkonen, and Erno Lehtinen. 2019. "Effects of a Mathematics Game-Based Learning Environment on Primary School Students' Adaptive Number Knowledge." (274163).

Bringula, Rex P., Francis Arlando, L. Atienza, Jane Mangubat, Maristela Roxas, John Paul, and P. Miranda. 2025. "Impact of Intelligent vs Non-Intelligent MCSCL on Mathematics Performance: A Comparative Study of Grade 5 Students Rex." *Acta Psychologica* 260(April):105507. doi: 10.1016/j.actpsy.2025.105507.

Dhuha, Shela Hadri, Nani Kurniati, Ulfa Lu, Harry Soepriyanto, Pendidikan Matematika, and Universitas Mataram. 2024. "Pengaruh Model Game Based Learning Menggunakan Aplikasi Quizizz Terhadap Minat Dan Hasil Belajar Matematika." *Mandalika Mathematics and Education Journal* 6:775–84.

Do, Hai-ninh, Bich Ngoc Do, and Minh Hue Nguyen. 2023. "Heliyon 3How Do Constructivism Learning Environments Generate Better Motivation and Learning Strategies ? The Design Science Approach." *Heliyon* 9(12):e22862. doi: 10.1016/j.heliyon.2023.e22862.

Dorji, Nidup, and Karma Sonam Rigdel. 2024. "The Effect of Games and Simulations in Learning Mathematics : A Quasi-Experimental Study." 20(2):1–15.

Duval, Sue, and Richard Tweedie. 2000. "Trim and Fill: A Simple Funnel-Plot-Based Method." *Biometrics* (June):455–63.

Erşen, Zeynep Bahar, Ebru Ergül, and E. Trends. 2022. "Trends of Game-Based Learning in Mathematics Education : A Systematic Review To Cite This Article : Trends of Game-Based Learning in Mathematics Education : A Systematic." *JCER : International Journal of Contemporary Educational Research* 9(3):603–23. doi: 10.33200/ijcer.1109501.

Fadillah, Anggun Nur, Wildansyah Lubis, Elvi Mailani, and Lidia Simanihuruk. 2025. "Pengaruh Media Pembelajaran Papan Perkalian Montessori Terhadap Hasil Belajar Perkalian Kelas Iv Sdn 054907 Gang Sentosa." 5(4):5187–95.

Fransisco, Teofilo G. 2020. "Game- Based Activity : The Effect on Students ' Learning in Mathematics." (2011).

Higgins, Julian P. T., Simon G. Thompson, Jonathan J. Deeks, and Douglas G. Altman. 2003.

"Measuring Inconsistency in Meta-Analyses." *Education and Debate* 557–60.

Ihsan, Muh, Herna, and Aprisal. 2024. "Pengaruh Penggunaan Media Game Edukasi Wordwall Terhadap Keaktifan Dan Hasil Belajar Matematika Siswa Kelas Viii Smp Negeri 5 Tinambung." *PEDAMATH : Journal on Pedagogical Mathematics* 7(1):39–49.

Islam, Kireida, Kokom Komalasari, Iim Masyitoh, Juwita, and Ismi Adnin. 2024. "Pengaruh Model Pembelajaran Game Based Learning Terhadap Motivasi Belajar Peserta Didik." *Jurnal Ideas Publishing* 10(2018):619–28. doi: 10.32884/ideas.v10i3.1640.

Iwen, Chun-ming Hung, and Huang Gwo-jen Hwang. 2014. "Effects of Digital Game-Based Learning on Students' Self- Efficacy, Motivation, Anxiety, and Achievements in Learning Mathematics." *Computers & Education* 1:151–66. doi: 10.1007/s40692-014-0008-8.

Julianty, Siti Indah. 2018. "Perbedaan Motivasi Belajar Ditinjau Dari Metode Ceramah Dan Media Powerpoint Dalam Pembelajaran Matematika Pada Siswa Skripsi."

Kudri, Al, and Maisharoh. 2021. "Pengaruh Media Pembelajaran Kahoot Berbasis Game Based Learning Terhadap Hasil Belajar Mahasiswa." *EDUKATIF : JURNAL ILMU PENDIDIKAN* 3(6):4628–36.

Lakens, Daniël. 2013. "Calculating and Reporting Effect Sizes to Facilitate Cumulative Science : A Practical Primer for t -Tests and ANOVAs." 4(November):1–12. doi: 10.3389/fpsyg.2013.00863.

Liberati, Alessandro, Douglas G. Altman, Jennifer Tetzlaff, Cynthia Mulrow, Peter C. Gøtzsche, and P. A. John. 2009. "& Reporting and Meta-Analyses of Studies That Evaluate Healthcare Interventions : Explanation and Elaboration." *BMJ*. doi: 10.1136/bmj.b2700.

Makarim, Nabil, and Maman Fathurrohman. 2023. "Meta Analisis : Pengaruh Pembelajaran Berbasis Permainan Terhadap Motivasi Dan Hasil Belajar Matematika Siswa." *Journal on Education* 06(01):10284–93.

Mansureh, Kebritchi, Atsusi Hirumi, and Haiyan Bai. 2020. "Author ' s Personal Copy Computers & Education The Effects of Modern Mathematics Computer Games on Mathematics Achievement and Class Motivation." *Computers & Education* 55:427–43. doi: 10.1016/j.compedu.2010.02.007.

Mcleod, Saul. 2025. "Piaget ' s Theory and Stages of Cognitive Development." *Simply Psychology* 1–52. doi: 10.5281/zenodo.15241970.

NCTM. 2000. *Principles and Standards for School Mathematics*.

Nurjiah, Melan, and Jean Elikal Marna. 2025. "Pengaruh Game-Based Learning Berbantu Wordwall Terhadap Hasil Belajar Siswa." *Jurnal Pendidikan Dan Pembelajaran* 5(2):1–13.

Nursalam. 2020. *Literature Systematic Review Pada Pendidikan*. edited by S. K. Dr. Tintin Sukartini, S. K. M.Kes Diah Priyantini, and N. Ns Dluha Maf'ula, S.Kep.

Nurul, Dk, Najiah Pg, Abu Bakar, and Masitah Shahrill. 2023. "Digital Escape Game and Students ' Learning Outcomes in Mathematics : Experience From Brunei." (December):1–14. doi: 10.1177/21582440231216838.

OECD. 2023. *PISA 2022 Results : The State of Learning and Equity in Education*. Vol. I. Paris: OECD Publishing.

Pakpahan, Farida Hanum, Marice Saragih, Magister Pendidikan, Bahasa Inggris, and Amik Widyaloka Medan. 2022. "Theory Of Cognitive Development By Jean Piaget." *JOURNAL OF APPLIED LINGUISTICS* 2(1):55–60. doi: 10.52622/joal.v2i2.79.

Palmer, David. 2005. "A Motivational View of Constructivist- Informed Teaching." *International Journal of Science Education* 27(15):1853–81. doi:

10.1080/09500690500339654.

Pan, Ai-jou, Yea-tzu Yuan, and Pao-nan Chou. 2025. "Incorporating PaGamO and Postgame Group Discussions into an Elementary Mathematics Course : An Experimental Study." (1):1–16. doi: 10.1177/21582440251329698.

Rahim, Mujeebur, Lubna Ali Mohammed, Saba Batool, S. The, Mujeebur Rahim, Lubna Ali Mohammed, and Saba Batool. 2025. "The Effect of Kahoot as a Gamification- Based Assessment Tool on Primary Students ' Academic Achievement in Mathematics To Cite This Article : The Effect of Kahoot as a Gamification-Based Assessment Tool on Primary Students ' Academic Achievement in Mathematics."

Rahimi, Seyedahmad, Valerie J. Shute, Curt Fulwider, Katie Bainbridge, Renata Kuba, Xiaotong Yang, Ginny Smith, Ryan S. Baker, and Sidney K. D. Mello. 2022. "Computers & Education Timing of Learning Supports in Educational Games Can Impact Students ' Outcomes." *Computers & Education* 190(July):104600. doi: 10.1016/j.compedu.2022.104600.

Rahmania, Aisyah, Erna Suwangsih, and Primanita Sholihah Rosmana. 2024. "Pengaruh Games Based Learning Quizziz Terhadap Hasil Belajar Kemampuan Operasi Hitung Campuran Siswa Kelas Vi Aisyah Rahmania 1 , Erna Suwangsih 2 , Primanita Sholihah Rosmana 3 Progam Studi Pendidikan Guru Sekolah Dasar, Universitas Pendidikan Indonesia." 10(16):25–33.

Retnawati, Hera, Ezi Apino, Kartianom, Hasan Djidu, and Rizqa D. Anazifa. 2018. *Pengantar Analisis Meta*. Pertama. edited by E. Apiano. Yogyakarta: Parama Publishing.

Rosenthal, Robert. 1979. "The " File Drawer Problem " and Tolerance for Null Results." *Psychological Bulletin* 86(3):638–41.

Rosyida, Risma Hanifatur, and Wulan Sutriyani. 2026. "Pengaruh Model Game Based Learning Menggunakan Gimkit Terhadap Hasil Belajar Matematika Di Sekolah Dasar The Effect Of A Game-Based Learning Model Using Gimkit On Mathematics Learning Outcomes In Elementary Schools." *JPMS (Jurnal Pembelajaran Dan Matematika Sigma)* 12(1):17–23.

Singh, Vedmeena. 2025. "Game Based Learning and Its Impact on Student Engagement and Academic Achievement." *International Journal for Multidisciplinary Research (IJFMR)* 7(2):1–8.

Sterne, Jonathan A. C., Alex J. Sutton, John P. A. Ioannidis, Norma Terrin, David R. Jones, and Joseph Lau. 2011. "Recommendations for Examining and Interpreting Funnel Plot Asymmetry in Meta-Analyses of Randomised." (fig 1):1–8. doi: 10.1136/bmj.d4002.

Sulmiati. 2022. "Pengaruh Game Online Terhadap Hasil Belajar Mata Pelajaran Matematika Siswa Kelas V Sdn 3 Banjarsari." *Renjana Pendidikan Dasar* 2(3).

Sumale, Lufna, Abdul Wahab Abdullah, and Bertu Rianto Takaendengan. 2024. "Students ' Mathematics Learning Achievement At Vocational School : An Experimental Study Of Using." 4(1):142–49.

Supriadi, Nanang, Kartika Ramadhona, Dona Dinda Pratiwi, and Santi Widyawati. 2020. "Concept Understanding Skills and Mathematical Problem-Solving Skills in Algebraic Materials: The Effect of DMR Learning Model Assisted by Dragonbox Puzzle Game During The Covid-19 Pandemic." *Al-Jabar: Jurnal Pendidikan Matematika* 11(1):191–98.

Tokac, U., E. Novak, and Thompson. 2019. "Effects of Game-Based Learning on Students' Mathematics Achievement: A Meta-Analysis."

Ully, Sonali Arta, and Ika Parma Dewi. 2022. "Pengaruh Game-Based Learning Menggunakan Aplikasi Quizizz Terhadap Hasil Belajar." *Jurnal Vocational Teknik*

Elektronika Dan Informatika 10(4).
Wardani, Winda Risma, Aan Nurfahrudianto, and Muhamad Basori. 2024. "Pengaruh Model Pembelajaran Digital Game Based Learning (DGBL) Terhadap Hasil Belajar Siswa SDN Manggis." 1300–1310.
Widiyasari, Ririn. 2025. "Pengaruh Model Game-Based Learning Berbatuan Kahoot Terhadap Motivasi Belajar Dan Hasil Belajar Matematika Siswa." *JIIP - Jurnal Ilmiah Ilmu Pendidikan* 8(April).