A Meta-Analysis of Numerical Aptitude's Effect on Learning Outcomes and Mathematical Ability

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***Abstract* – This study examines the effect of numerical aptitude on junior high school students learning outcomes and math abilities. Data were collected using sample size and Pearson correlation coefficient. The data analysis technique with a meta-analysis included publication bias, forest plot, effect size calculation, and heterogeneity test. The effect size of numerical aptitude on learning outcomes and mathematical ability was 0.60 and 0.41 with strong and medium categories, respectively. The results show that numerical aptitude improves math learning outcomes. Other meta-analysis studies find no publication bias. The study improves junior high math learning by identifying numerical talent.**

***Keywords* – effect size, learning outcomes, mathematical ability, meta-analysis, numerical aptitude.**

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1. Introduction

Learning outcomes are statements of expectations that students want to know, understand, and can demonstrate at the end of each learning period [1]. Learning outcomes can be expressed as knowledge, skills, or attitudes. The assessment carried out by the teacher covers all domains of learning outcomes, namely cognitive abilities (knowledge), skills (psychomotor), and attitude abilities (affective) [2]. According to government regulation number 19 of 2005, Article 63 requires educators, education units, or the government to measure learning outcomes at the elementary and upper secondary levels [3]. In Article 64, instructors examine learning outcomes daily, mid-semester, semester, and grade raise examinations to monitor the process, progress, and development.

Mathematical ability is a cognitive ability that is also the domain of learning outcomes. Several theory-based groupings explain the domain of mathematical ability. According to Karsenty [4], mathematical ability is finding, processing, and understanding information in math. Meanwhile, according to Campbell [5], mathematical ability consists of mathematical problem-solving and numerical ability. Mathematical problem solving is obtained from activities to represent abstract mathematical problems into contextual problem solving to produce solutions [5]. Numerical abilities include simple arithmetic problems, counting, number comparisons, and basic number representations. From a developmental point of view, Gaber and Schlimm [6] suggest that geometric and numerical skills are basic math skills. Mathematical ability in this study as the dependent variable consists of cognitive competence, ability to solve story problems, communication skills, problem-solving skills, mastery of concepts, and critical thinking skills.

Empirical studies to investigate the relationship between numerical aptitude abilities and learning outcomes and mathematical abilities have been carried out by academics, researchers, and students. The contribution of this empirical study has tremendous implications for information on the effect of numerical talent on learning outcomes and mathematical abilities. These implications provide information that learning to improve learning outcomes and mathematical abilities can identify students' numerical talents. Numerical talent predicts school and college success [7], [8], [9], [10], [11], [12], [13], [14], [15].

Several research studies have examined the relationship between numerical aptitude skills learning outcomes, and mathematical abilities. The results show that numerical aptitude significantly contributes to the two dependent variables. However, some studies report results that fail to replicate these two relationships. The research study used in this meta-analysis study by Lestari et al. [16] showed that numerical aptitude negatively contributes to mathematics learning outcomes. However, the other seven studies indicated a favorable and significant influence on mathematics learning results. In addition, the results of research studies show differences in the influence of numerical talent on the two dependent variables. Research studies related to numerical aptitude on mathematics learning outcomes with effects in the categories: very strong [17], [18]; strong [19], [20]; moderate [21]; low [22]. The effect on other dependent variables is a strong category [23], [24]; moderate [25], [26], [27], [28]; low [28], [29]. Based on the inconsistency of the results of these research studies, it is necessary to comprehensively evaluate the relationship between numerical aptitude, learning outcomes, and mathematical abilities—a comprehensive evaluation utilising a meta-analysis methodology to synthesize study results that match the researcher-specified criteria.

The literature analysis in this study was carried out by grouping the results of research studies that used the same design and hypotheses based on statistical data that was systematically summarised. The influence of numerical aptitude on Indonesian junior high school students learning outcomes and mathematical ability is examined using an ex-post facto research design. Statistical data were identified and tabulated based on data information: Pearson correlation coefficient, *t*-test or *F*-test results, and sample size used in the study. The results of grouping research studies with varied study outcomes are then synthesised using a quantitative method known as meta-analysis. *Meta-analysis* is a statistical method used to integrate, synthesise and interpret experimental findings from individual research studies [30]. The study, using a meta-analysis approach, aims to quantitatively combine the results of different research conducted independently based on the two dependent variables: learning outcomes and mathematical abilities.

The relevant study uses a meta-analysis approach based on a literature review on identifying the influence of talent ability consisting of the dependent variables: mathematical ability, difficulty in reading and mathematics, and mathematics learning outcomes, as well as gender differences. Schneider et al. [31] performed a meta-analysis on 45 research articles to assess how numerical skill affects mathematical ability. Numerical ability consists of comparing numerical quantities in the form of symbols and non-symbols. At the same time, mathematical ability consists of the ability to count, do arithmetic, and do algebra. Xie et al. [32] also performed a meta-analysis to determine how spatial aptitude affects mathematical ability based on moderator variables, including the numerical ability (arithmetic) and logical thinking, as well as age: children, adolescents, and adults. The research study used 73 research results published between 2008 and 2018. Peng and Fuchs [33] synthesised 29 research studies published between 1963 and 2013 by comparing learning difficulties based on working memory to understanding verbal and numerical related problems. The moderator variables consisted of reading and math difficulties. Chen and Li [34] synthesised research studies on the relationship between the ability to compare numbers in the non-symbolic form to mathematics learning outcomes. Synthesis of 42 research studies with moderator variables based on research design.

Otero et al. [35] conducted a meta-analysis using 83 study documents that compared cognitive reflection abilities to cognitive abilities and numeracy skills. Cognitive ability moderators include working memory, mechanical-spatial, verbal, numerical, and cognitive intelligence. Syzmanowicz and Furnham [36] examined 93 research studies comparing talent abilities by gender. The dependent variable consists of available talent and logical, spatial, and verbal abilities. Singer and Strasser [37] examined 68 research studies with 210 available descriptive data. A research study looked at the relationship between arithmetic ability and reading learning outcomes that pays attention to moderator variables consisting of orthographic transparency and the use of tests using or not using time.

This meta-analytical study comprises an Indonesian junior high school student research study published between 2014 and 2021. No meta-analysis has particularly examined the effect of numerical aptitude on learning outcomes and mathematical ability. Several studies that used meta-analysis found that the learning model improved learning outcomes and math skills. They found that cooperative learning models improve math learning outcomes [38], [39], [40] and math skills [41], [42, [43]. However, the six research studies used descriptive data comparing the results of the two learnings in the experimental and control classes using standard deviation, mean data, and sample size. Next, this study explains the analytical results with a summary effect size, forest plots for each analysis, and image plots for the overall effect size. In addition, funnel plot results were utilised to reveal biases against research studies. This study used the Fail-Safe *N* (FSN), regression, and rank correlation approach to validate the funnel plot method's subjective visual inspection to identify similarly biased articles.

This meta-analysis analyses how numerical talent affects learning and math skills. The research study uses samples from Indonesia published in journals or seminars indexed by Garba Reference Digital (GARUDA), Google Scholar, or Science and Technology Index (Sinta) between 2014 and 2021. Questions in this study:

RQ_1: What is the size of the summary effect of numerical aptitude on mathematics learning outcomes?

RQ_2: What is the size of the summary effect of numerical aptitude on mathematical ability?

RQ_3: How does the identification of bias in research studies relate to numerical aptitude on learning outcomes and mathematical ability?

This study aims to improve the learning outcomes and mathematical abilities of junior high school (JHS) students in Indonesia by focusing on their numerical talents. In addition, this study also contributes to understanding searching for literature articles, computing summary effect estimates, and finding biases in research study publications. This study used a meta-analysis, unusual or never done by researchers or academics in Indonesia or other Asian nations, to identify the influence of numerical aptitude on learning outcomes and mathematical ability.

2. Materials and Methods

2.1. Data Collection

The inclusion criteria for research studies that were eligible for use in the meta-analysis consisted of (1) at least three domain variables with independent variables: numerical aptitude and the dependent variable: learning outcomes and mathematical ability; (2) the research sample used junior high school students; (3) descriptive analysis data includes Pearson correlation coefficient (*r*), *t*-test or *F*-test results, and sample size (*N*); (4) research design using ex-post facto; (5) Indonesian or English manuscripts are available; and (6) scientific journal and seminar manuscripts from 2014 to 2021 are searchable by GARUDA, Google Scholar, or Sinta. Then, for exclusion criteria, if (1) the research study sample uses students with elementary, high school, or high school levels College; (2) the data from descriptive analysis only provides information on the Pearson correlation coefficient; (3) the dependent variable uses other than learning outcomes or mathematical abilities; (4) research design using other than ex-post facto design; and (5) the manuscript is published in the campus repository database, and the research results are still in the form of scientific work documents, namely theses.

Identify relevant research studies with systematic searches using the Google Scholar database. The search used a combination of terms related to the research topic area based on the inclusion criteria. The combination of terms included two groups of search terms related to the influence (contribution; correlation; relationship) of numerical aptitude ability with mathematics learning achievement (study outcome; learning achievement) and mathematical ability (cognitive competence; story problem-solving ability; communication ability; problem-solving ability; mastery of concepts; critical thinking skills). Figure 1 depicts the process of selecting research studies.

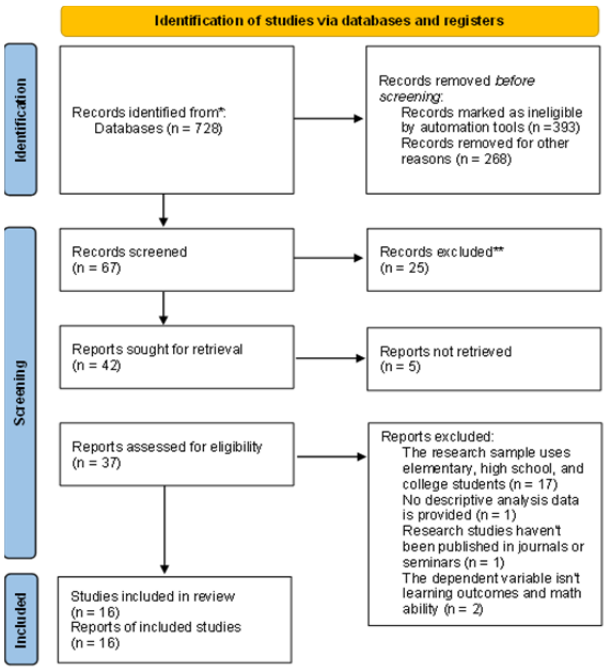


Figure 1. Research study selection process [45]

The process of identifying research study searches up to the stage of obtaining research studies that meet and use in a meta-analysis using the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) reporting procedure [44], [45],

[46]. The initial stage is identifying research studies based on the title using inclusion criteria. The search resulted in 728 documents which were reduced to 67 documents after finding invalid documents based on the selection of research study titles. After reviewing the documents based on the title selection, there were 25 documents published in the campus repository database. In the following process, five publication documents were issued by analysing the abstract section because the research study did not use an ex-post facto design. Then, the thirty-seven research studies that met the criteria for re-screening were obtained from as many as 17 research studies using research samples of elementary school, high school, and college students. The other four research studies were excluded due to incomplete descriptive analysis data (k = 1), documents not published in scientific journals or seminars (k = 1), and dependent variables other than learning outcomes and mathematical abilities (k = 2). In the final stage, the research study search method found 16 documents that met the inclusion criteria. Two independent experts (MRR and SH) checked the research selection, exclusion, and inclusion criteria in the literature search results to avoid reviewer bias.

2.2. Data Analysis

The descriptive analysis-based meta-analysis used the Pearson correlation coefficient and sample size from research studies. The correlation value shows the influence of numerical talent on learning outcomes and mathematical abilities. At the same time, the sample size indicates the number of respondents who participated in the study. However, suppose the data from the descriptive analysis only consists of the t-test or F-test values. In that case, the t-test and F-test values are transformed to r, respectively, using the formula $r = \frac{t}{\sqrt{t^2+N-2}}$, with $t = \sqrt{F}$ and N representing the sample size used in the study. Pearson correlation coefficient (r) and sample size (N) data from each study were collected in a *Notepad* file based on each dependent variable. The dependent variable consists of learning outcomes and mathematical ability. The analysis was also carried out separately based on the dependent variable using the *R* program (version 4.2.0) and *JASP* (version 0.16.3.0). The analytical procedure consists of converting the Pearson correlation coefficient (r) to Fisher (z) using the formula $z = 0.5 \times \log\left(\frac{1+r}{1-r}\right)$ ([47], [48]) and calculating the standard error (SE) based on the value of the variance of z for each research study. The results of the z and $SE(z)$ values were collected in the *SPSS* file and then analysed using the *JASP* program.

The analysis results using the *R* program consisting of the values of the Q-statistics and I^2 were used to identify the type of randomised model used in the meta-analysis based on the heterogeneity test criteria. The distribution of research study sample data meets heterogeneous conditions if the Q- value >df and p-value <0.05 or I^2 >50% [49]. Furthermore, a random effects model is used if the data distribution is heterogeneous and vice versa [50]. Each research study's effect size values are analyzed. The effect size category according to Cohen et al. [51] ie values greater than 0.81: very strong; 0.51–0.80: strong; 0.31–0.50: moderate; 0.11–0.30: weak; and 0.00–0.10: very weak.

Then *JASP* forest plots are used to identify bias in meta-analysis research projects. With funnel plots, FSN, regression, and rank correlation, publication bias was found. The forest plot shows each research study's impact size values and the cumulative effect size (M) values. The summary effect size value is used to convert the M value to the r-value by using the formula $r = \frac{\exp(2M)-1}{\exp(2M)+1}$. The r value shows the correlation or the magnitude of the influence of numerical talent on learning outcomes and mathematical abilities. Identifying publication bias using funnel plots and visual examination of impact size distributions for all research studies—observations outside or within the pyramid. If there is an effect size outside the pyramid, it is distributed in the middle and top. However, this is called publication bias if most studies lie near the base of the funnel plot or along a single axis [48]. Furthermore, according to Sutton et al. [52], if the distribution of effect size data on both sides of the funnel plot reflects each other, there is no publication bias. Identifying bias against research studies using funnel plots shows a subjective assessment that is not strong and valid evidence for that conclusion. So that the identification of other biases in this study also uses the rank correlation method [53] and regression [54] as well as the FSN method [55]. The criteria for identification of publications are biased using rank correlation and regression methods based on p-value, with a p-value >0.05, so there is no publication bias [54]. While the result criteria using the FSN method are based on the FSN value, $\frac{FSN}{5k+10} > 1$, with k representing the number of research studies [56].

3. Results

The study's results included heterogeneity tests, effect sizes, forest plots, and publication bias. Heterogeneity test for determining the type of effect model used in the meta-analysis. The effect size determines the magnitude of numerical aptitude's influence on learning outcomes and mathematical abilities. The forest plot describes the overall effect of the dependent variable (i.e., numerical aptitude) on the independent variable (i.e., learning outcomes and mathematical ability). Then, publication bias denotes identifying biased or unbiased conditions for the research studies used in the meta-analysis. The following description of the research results answers the three research questions.

3.1. Heterogeneity Test

The test for heterogeneity to identify the suitability of the data with the fixed effect or random effect model for further testing analysis. Each research study's heterogeneity test analysis results include sample size (*N*), Pearson correlation coefficient (*r*), and *t*-test or *F*-test values. Table 1 shows the results of the calculation analysis performed with the *R* program.

Table 1. Results of heterogeneity test

Independent Variable	Dependent variable	I^2	*Q*-Statistics		
			df	Value	*p*-value
Numerical aptitude ability	Outcomes of learning	92.7%	7	95.41	< 0.0001
	Mathematics ability	86.5%	8	59.40	< 0.0001

Table 1 shows the heterogeneity test results for the two dependent variables using the *Q*-statistical parameter. Each variable had a *p*-value <0.05 and a *Q*-value >*df*. These two research found heterogeneous sample data. Therefore population variance and sampling error affect effect size [57]. According to Huedo-Medina et al. [58], the heterogeneity test results employed the *Q*-statistic value. The *Q*-statistics cannot accurately measure meta-analysis studies' heterogeneity. As a result, the I^2 statistical value was employed in this study's other heterogeneity test. The I^2 statistic was unaffected by impact size and meta-analysis study number. The results of the I^2 values for the two dependent variables were respectively 92.7% and 86.5%, with high and moderate heterogeneity categories [48], [49], [59]. The analysis using the I^2 value also shows that research study data related to the influence of numerical talent on learning outcomes and mathematical abilities meet heterogeneous conditions. So, the analysis uses a random effects model to meet the heterogeneous assumption [50], [60]. Thus, obtained for both dependent variables meet the assumption of heterogeneity. To analyse further, use the random effects model to calculate the summary and each research study effect size.

3.2. Effect Size

Each research study employed effect size calculation to estimate the impact of numerical aptitude on JHS students' learning outcomes and math abilities. Table 2 displays the *R* program's effect size estimates for the independent variable on the two dependent variables.

Table 2. Calculated effect size results

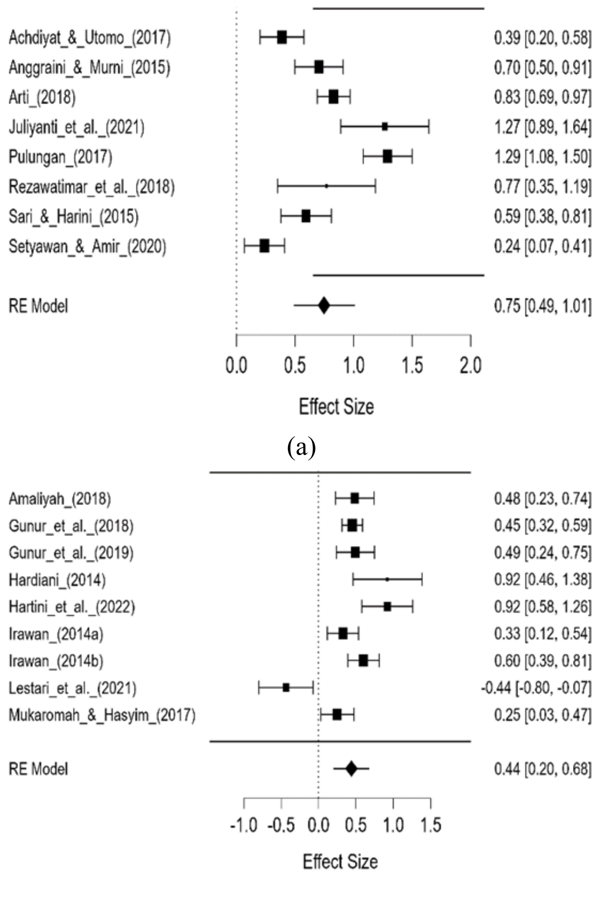
Code	Author(s) and Years	SMD
LO1	Achdiyat & Utomo (2017)	0.3884
MA1	Amaliyah (2018)	0.4847
LO2	Anggraini & Murni (2015)	0.7026
LO3	Arti (2018)	0.8291
MA2	Gunur et al. (2018)	0.4513
MA3	Gunur et al (2019)	0.4935
MA4	Hardiani (2014)	0.9223
MA5	Hartini et al. (2022)	0.9202
MA6	Irawan (2014a)	0.3272
MA7	Irawan (2014b)	0.6013
LO4	Juliyanti et al. (2021)	1.2671
MA8	Lestari et al. (2021)	-0.4356
MA9	Mukaromah & Hasyim (2017)	0.2501
LO5	Pulungan (2017)	1.2895
LO6	Rezawatimar et al. (2018)	0.7684
LO7	Sari & Harini (2015)	0.5943
LO8	Setyawan & Amir (2020)	0.2384

Note: SMD – Standardized Mean Difference; LO – Learning Outcomes; MA – Mathematics Ability.

Table 2 shows the effect size of numerical talent on learning outcomes and mathematical abilities. According to Cohen et al. [51], i.e., the effect size category values greater than 0.81: very strong; 0.51 – 0.80: strong; 0.31 – 0.50: moderate; 0.11 – 0.30: weak; and 0.00 – 0.10: very weak. The effect size category of numerical aptitude research studies on mathematics learning outcomes consists of 3 research studies with a very strong effect size category [17], [18], [20] and three research studies with a strong effect size [19], [21], [22]. The other two research studies have weak [61] and moderate effect sizes [62], respectively. While the effect size category on mathematical ability consists of 2 research studies with a very strong effect size category [23], [24], one research study with a strong category [28], four studies with a moderate category [25], [26], [27], [28] and other studies with weak effect size categories [29]. Then, research studies do not positively contribute to mathematical ability [16].

3.3. Forest Plot

Other analysis in this study used forest plot analysis to determine the overall effect size or summary effect size of the combined research studies used in the meta-analysis. The data from the calculation analysis using the *R* program and then plotting using *JASP* obtained the forest plot results in Figure 2.



(a)

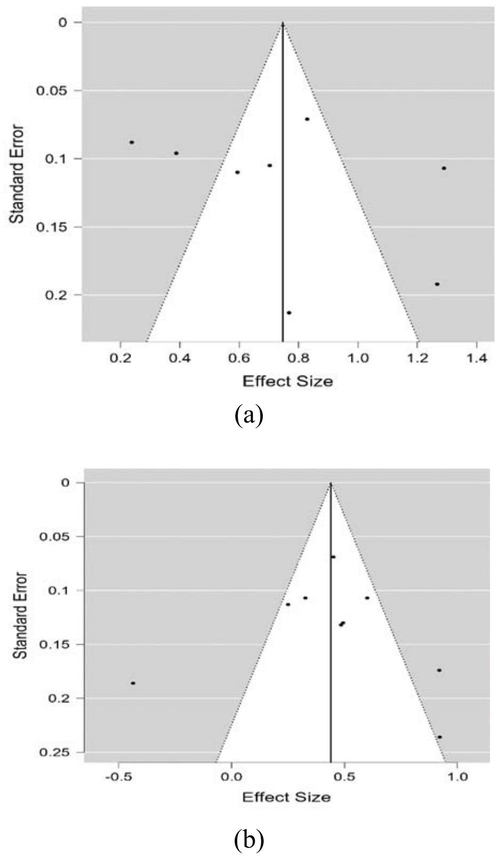
(b)

Figure 2. The forest plot analysis measures the effect of numerical talent on (a) mathematics learning outcomes and (b) mathematical ability

In Figure 2, the forest plot analysis shows that numerical aptitude has a summary impact size of 0.75 [95%-CI: 0.49;1.01] on learning outcomes and 0.44 [95%-CI: 0.20;0.68] on mathematical ability. When the calculation is converted to an *r*-value using the *R* program, the two effect size results are obtained at 0.60 and 0.41, respectively, according to Cohen et al. [49] have effect sizes with strong and moderate categories. This study found that the influence of numerical talent on learning outcomes and mathematics abilities of JHS students is 0.60 and 0.41, respectively, with strong and moderate categories. The contribution of this study provides information that learning to improve learning outcomes and mathematical abilities can be identified based on the numerical talents of JHS students in Indonesia.

3.4. Biased Publication

The funnel plot, FSN, regression, and rank correlation methods identify publication bias in the following analysis. These three strategies identified biased conditions in meta-analysis research studies. Figure 3 showed the funnel plot findings from the calculation analysis using *R* and plotted using *JASP*.



(a)

(b)

Figure 3. The funnel plot of numerical talent's effect size on (a) mathematics learning outcomes and (b) mathematical ability

Figure 3 shows the funnel plot analysis of impact size data from each meta-analysis study. The position inside or outside the pyramid graphically identifies the distribution of impact size data. Research outside the pyramid has effect sizes between the center and the top. However, publication bias develops if the funnel plot graph has most research studies at the bottom or in one vertical line [48]. The visual distribution of effect size data in Figures 3(a) and 3(b) shows that it is symmetrically distributed around a vertical line of a closed circle in a pyramid. The plot analysis results show no indication of bias even though there is a research study in Figure 3(a) with a closed circle outside the pyramid with a position at the bottom of the pyramid. Identification of publication bias by funnel plot analysis shows a subjective assessment so that it does not become valid evidence to show research study samples indicated publication bias. Therefore, regression, rank correlation, and FSN methods are employed to support funnel plot identification results.

The regression and correlation rank method, as well as the FSN technique findings, were calculated using data from the *R* program's effect size calculation analysis. Tables 3 and 4 provide the coefficients and *p*-values of the two techniques for each dependent variable.

Table 3. Rank correlation and regression calculation results

Independent Variable	Dependent Variable	RCM		RM	
		Coef.	*p*-value	Coef.	*p*-value
Numerical aptitude ability	Outcomes of learning	0.286	0.399	1.074	0.283
	Mathematics ability	0.141	0.600	0.333	0.739

Note. RCM – Rank Correlation Method; RM – Regression Method; Coef. – Coefficient.

Table 4. Calculation results using the FSN method

Independent Variable	Dependent variable	*k*	*FSN*	5*k* + 10
Numerical aptitude ability	Outcomes of learning	8	1022	50
	Matematics ability	9	364	55

The regression and rank correlation calculations in Table 3 yielded *p*-values of 0.283 and 0.399 for the mathematics learning outcome variable and 0.739 and 0.600 for the mathematical ability variable, all greater than 0.05. This study found no publication bias because the funnel plot graph is symmetrical [54]. The results of the next study in Table 4 obtained FSN values for each dependent variable of 1022 (k = 8) and 364 (k = 9) obtained FSN values >5k +10. According to Mullen et al. [56], meta-analysis research investigations are not biased toward publication.

4. Discussion

This study examines the impact of numerical aptitude on students' learning outcomes and mathematical abilities in Indonesia. This study uses descriptive data from 2014–2021 Google Scholar research results. Identification of research data using the Pearson correlation coefficient, the value of the t-test or F-test results, and the sample size obtained in 16 research studies, with one research study containing two descriptive analysis data based on the variable of mathematical ability. The meta-analysis found that numerical aptitude had a 0.75 [95%-CI: 0.49; 1.01] effect size on learning outcomes and 0.44 [95%-CI: 0.20;0.68] on mathematical ability. Therefore, the effect of numerical talent on the learning outcomes and mathematical abilities of JHS students is 0.60 and 0.41, with strong and moderate effect size categories, respectively, based on the conversion results.

The following research studies are relevant to the meta-analysis method for figuring out how talent affects the dependent variables: mathematical ability [31, 32, 35], reading ability [37], mathematics learning outcomes [34], and based on gender differences [36]. The meta-analysis study by Schneider et al. [31] found that numerical aptitude, both symbolic and non-symbolic, had impact sizes of 0.302 [95%-CI: 0.243;0.361] and 0.241 [95%-CI: 0.198;0.284] on mathematical ability. Another meta-analysis study by Xie et al. [32] also identified the ability of aptitude for mathematics ability. Spatial aptitude positively and significantly contributes to the mathematical ability by 0.27 [95%-CI: 0.24;0.32]. The summary effect size on moderator variables shows a positive and substantial influence: numerical ability (0.22 [95%-CI: 0.15;0.28]), arithmetic ability (0.25 [95%-CI: 0.21;0.29]), logical reasoning (0.32 [95%-CI: 0.25;0.40]), and geometric ability (0.30 [95%-CI: 0.22;0.40]). Other moderating variables were based on age: child's age (0.28 [95%-CI: 0.25;0.34]); adolescents (0.28 [95%-CI: 0.05;0.34]); and adult age (0.14 [95%-CI: 0.08;0.36]). The two meta-analyses demonstrate that numerical or spatial aptitude positively and significantly affects mathematical ability with a weak impact size category. In addition, spatial aptitude ability has an effect size with weak categories for the moderator variables: numerical aptitude ability and adolescent age in high school students.

Another study by Chen and Li [34] synthesised studies related to the relationship between the ability to compare numbers in the non-symbolic form to mathematics learning outcomes. The study's results identified research studies based on research study designs using cross-sectional and longitudinal designs, each of which obtained an impact size of 0.20 and 0.24. The contribution of talent ability in comparing numbers in the non-symbolic form to mathematics learning outcomes with a weak effect size category. A meta-analysis study was also conducted by Otero et al. [35] by synthesising 83 study documents that compare the ability of cognitive reflection to cognitive abilities and numeracy skills. Cognitive abilities include working memory, mechanical-spatial, verbal, numerical, and cognitive intelligence. Cognitive reflection ability corresponded strongly with all cognitive and numeracy skills. This research study shows that cognitive reflection ability also contributes to numerical ability.

Research by Syzmanowicz and Furnham [36] compared talent abilities based on gender differences. The results showed that the summary effect size for the overall talent ability variable based on gender was 0.37 [95%-CI: 0.33;0.41]. Other research results are based on each variable of talent ability: mathematical/logical intelligence (0.44 [95%-CI: 0.40;0.48]); spatial (0.43 [95%-CI: 0.34;0.42]); and verbal (0.07 [95%-CI: 0.03;0.11]). Except for the variable of verbal intelligence, these findings suggest that disparities between men and women in other abilities and talents have a moderate influence. The research sample with the male gender provides a much greater difference in verbal intelligence than women. Singer and Strasser [37] conducted a subsequent study to determine the effect of arithmetic competence on reading learning results. The results showed that arithmetic talent contributed to reading learning outcomes by 0.55 with a strong impact size. According to relevant research and literary studies, numerical or other talents positively and significantly affect learning outcomes and mathematical ability. Thus, the results of this study are expected to provide information on the effect of numerical talent on learning outcomes and mathematical abilities globally.

Other meta-analytical analyses in this study found bias in the research findings. Use funnel plots, FSN, regression, and rank correlation to find publication bias. The results of identifying publication bias using the funnel plot method using visual assessment show that the effect size data distribution for the two dependent variables is distributed symmetrically around the vertical line. The effect size data distribution consists of a closed circle in a pyramid. Although the distribution of effect size data for mathematics learning outcomes factors is outside the pyramid and at the bottom, it does not bias this study's sample. Visual analysis of the funnel plot does not give convincing evidence of publication bias in research study samples because it is subjective. Therefore, other identification uses FSN, regression, and rank correlation methods. Based on the calculation results for the rank correlation and regression methods of the learning outcomes variables, p-values of 0.399 and 0.283 were obtained (p-value >0.05). The same results were also obtained for both methods for the variable of mathematical ability. Each had a p-value larger than 0.05 (with p-values of 0.600 and 0.739). The meta-analysis of learning outcomes and mathematical abilities showed no publication bias based on the p-value. Other identification results using the FSN method for each dependent variable obtained FSN values of 1022 (with k = 8) and 364 (with k = 9), indicating the condition of the FSN value being more significant than $5k + 10$. These conditions identified no indication of publication bias.

The meta-analysis study by Schneider et al. [31] also identifies biases against publications or research study documents. Forest patches are identified after and before Trim and Fill. The results of this method have implications for the funnel plot with the insertion of fictional effect sizes on the left side of the pyramid to achieve a symmetrical distribution of effect size data. The FSN method was also used in their research to identify the bias toward the publications used. With k = 284, the FSN of 9101 was greater than $5k + 10$. The results of the two methods also showed no indication of publication bias. Chen and Li [34] also identified a bias towards study documents in their research. Trim and Fill, regression, rank correlation, and visual funnel plot analysis are used. The identification results using funnel plots showed a statistically significant positive correlation that is slightly more likely to be published than unpublished. Another approach using rank correlation and regression methods obtained coefficients of 0.33 and 1.37 and p-values of 0.005 and 0.17. So, based on the regression method, the requirements for the p-value are not met with a p-value smaller than 0.05. These conditions suggest publication bias. Thus they employ the Trim and Fill method to validate biased information in their research. The funnel plot's impact size data is symmetrical because six studies are "missing" on the left side.

5. Conclusion

The meta-analysis of the literature study shows that numerical talent has a favorable and significant effect on mathematics learning results and junior high school students' mathematical abilities in Indonesia. The magnitude of the impact size of numerical aptitude on mathematics learning outcomes and mathematics ability is 0.60 and 0.41, respectively, with strong and moderate categories. The results of other studies showed no bias towards publications used in the meta-analysis studies. The research limitation is that it uses a study sample of research conducted in Indonesia between 2014 and 2021. So that the research results will only contribute information to improve student learning outcomes and mathematical abilities in Indonesia by paying attention to students' numerical talents. Another constraint is that the research studies included were collected from the Google Scholar database and were published in indexed journals or seminars by Sinta, GARUDA, and Google Scholar. Therefore, for further research, it is recommended to use the results of research studies sourced from international databases and pay attention to the credibility of scientific journals or seminars. Nevertheless, this study's findings improve our understanding of summary effect size analyses and publication biases. Furthermore, investigations using these meta-analysis approaches are still uncommon and have never been conducted by researchers or academics in Indonesia or other Asian nations.

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Appendix. Research study data used in the meta-analysis

Author(s) & years	Access of document article
Achdiyat & Utomo (2017)	https://journal.lppmunindra.ac.id/index.php/Formatif/article/view/2234/1694
Amaliyah (2018)	https://journal.lppmunindra.ac.id/index.php/alfarisi/article/view/5666/2937
Anggraini & Murni (2015)	https://isre.prosiding.unri.ac.id/index.php/ISRE/article/view/3114/3037
Arti (2018)	http://ejournal.umpwr.ac.id/index.php/ekuivalen/article/view/4373
Gunur et al. (2018)	https://journal.uin-alauddin.ac.id/index.php/Mapan/article/view/5862
Gunur et al (2019)	https://journal.uny.ac.id/index.php/pythagoras/article/view/27250/pdf
Hardiani (2014)	https://jurnalbeta.ac.id/index.php/betaJTM/article/view/44/58
Hartini et al. (2022)	http://journal.unj.ac.id/unj/index.php/jrpmj/article/view/25695/12089
Irawan (2014)	https://journal.lppmunindra.ac.id/index.php/Formatif/article/view/138/132
Juliyanti et al. (2021)	https://mathjournal.unram.ac.id/index.php/Griya/article/view/65/53
Lestari et al. (2021)	https://doi.org/10.29303/griya.v1i2.45
Mukaromah & Hasyim (2017)	https://jurnal.stkippgritulungagung.ac.id/index.php/jp2m/article/view/294/830
Pulungan (2017)	http://jurnal.iain-padangsidimpuan.ac.id/index.php/LGR/article/view/1539/1266
Rezawatimar et al. (2018)	http://www.jim.unsyiah.ac.id/pendidikan-matematika/article/view/5043/3936
Sari & Harini (2015)	https://doi.org/10.30738/.v3i1.287
Setyawan & Amir (2020)	https://doi.org/10.46918/equals.v3i2.757