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A meta-analysis study on the effectiveness of a cooperative learning model on vocational high school students' mathematics learning outcomes

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Cooperative learning takes place when students work together in small groups to help each other comprehend a subject. This meta-analysis aims to determine the impact of cooperative learning on vocational high school students' mathematics learning results compared to those that pertain to conventional learning. Data from 22 research studies, including the sample size, standard deviation, and mean for both the experimental and control groups and other information, were collected using descriptive analysis. The data analysis technique used meta-analysis on forest plots, with analytical techniques including heterogeneity testing, effect size calculation, summary effect calculation using a random-effects model, and identification of publication bias. The results showed that the effectiveness of cooperative learning was 0.89, which gave a medium effect on the mathematics learning outcomes of vocational high school students. The cooperative learning model also provides a measure of higher effectiveness in grade 11 than grade 10 and learning at a sample size of 1-30 students compared to more than 30 students. The effectiveness of cooperative learning on mathematics learning outcomes in the medium effect category, on the other hand, is dependent on grade level variables and sample size. This meta-analysis research provides information to teachers in Indonesia to implement cooperative learning based on the level and number of students in the class to improve the mathematics learning outcomes of vocational high school students.

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Introduction

The international experience reveals that educators have an active role in comprehending and implementing learning activities (Sultana et al., 2009). According to the perception of some teachers in South Sulawesi, Indonesia, the application of critical thinking skills in the mathematics learning process requires support from a variety of sources, including the use of the learning model's suitability with the subject matter and the teacher's knowledge of critical thinking skills indicators (Ridwan et al., 2022). As a result, altering the application of learning is becoming more complex (Smets & Struyven, 2018). Applying the same learning paradigm to pupils from different countries is challenging because they have different learning demands (Santangelo & Tomlinson, 2012). Using a successful learning model in one area and applying it in another area does not ensure success in enhancing learning results. The learning model must adapt to the material and pupils. In Indonesia, most schooling is done by memorization of concepts and formulas. The teacher's teaching method stresses remembering content rather than assessing and synthesizing it (Rodzalan & Saat, 2015; Wijaya et al., 2019). The lecture technique dominates teachers' learning efforts. Students become more passive and desperate for critical thinking when lecturers use the lecture method to convey concepts. (Baguma et al., 2019; Mustofa & Yuwana, 2016).

Students become passive learners when teachers do not enhance their comprehension of the content. If the problem is modified to the level of cognitive aptitude, a child can understand it well. Vygotsky (1978) states that a problem must be in the child's proximal zone. Thus, pupils need new information and mathematical problem-solving skills to help them think of new solutions to difficulties (Grugnetti & Jaquet, 2005). Mathematics learning will be more effective through group activities (Hadi, 2005), where all group members work together for success and common goals. Group work can foster natural social interaction (Zulkardi, 2002). Cooperative learning is a mode of instruction that relies on students cooperating to understand a subject better. According to John Dewey, cooperative learning, which began in the 1970s, was designed to involve students in groups while enhancing individual learning. The cooperative learning paradigm works best when students influence each other (Haller et al., 2000). In this scenario, the teacher can use the concept of group learning to help pupils recognize math difficulties. The cooperative learning model is one of the strategies developed in numerous nations (Rattanatumma & Puncreobutr, 2016). Cooperative learning is one of the most innovative educational approaches today (Surian & Damini, 2014).

Cooperative learning, in general, entails students working in small groups or teams to assist one another in understanding the subject matter (Slavin, 1989; Johnson et al., 2014). Cooperative learning is a learning strategy that enhances learning by engaging students at various knowledge levels in group activities. Cooperative learning has a different form of a model, with each having specific characteristics and advantages. The Johns Hopkins University School of Social Organization Center has created and analyzed a cooperative-based learning paradigm (Slavin & Cooper, 1999). The cooperative learning model consists of the Jigsaw model (Aronson et al., 1978), STAD (Student Teams–Achievement Division) and TGT (Teams–Games–Tournament) (Slavin, 1986), TAI (Team–Assisted Individualization) (Slavin et al., 1984), and CIRC (Cooperative Integrated Reading and Composition) (Stevens et al., 1987). According to Slavin (1983), the differences in cooperative learning are centered on two primary components: the reward system and student assignments. The three award structures are based on group incentives for each learning, group incentives for group output, and individual incentives. However, in other conditions, the application of cooperative learning is also without rewards. Students carried out a task structure centered on groups and individuals. The task structure based on groups describes all group members doing learning activities together and having the same responsibility in completing tasks. Then structure the tasks individually, which means that each member is responsible for each part of the task.

It is evident from the meta-analysis that applying the cooperative learning approach improves student learning outcomes (Bertuccia et al., 2016). Additionally, meta-analysis research indicates that innovative learning models, such as cooperative models with a student-centred approach and collaborative student learning activities, are more effective than traditional teacher-centred learning (Agustini et al., 2021; Capar & Tarim, 2015; Kalaian & Kasim, 2014; Kumar, 2017; Kyndt et al., 2013; Ridwan et al., 2021). Learning outcomes and social and emotional skills are quantifiable elements. Cooperative learning provides benefits for both students and teachers and it is the application to all levels of education (Saborit et al., 2016; Sharan, 2010). Cooperative learning approaches also help students improve cognitive and emotional skills (Parveen et al., 2017; Vega & Hederich, 2015). The cooperative learning paradigm works better for elementary and secondary school students than for college students (Hattie, 2009).

Cooperative learning activities significantly influence students' mathematics learning outcomes and social and emotional abilities. The average mathematical learning outcomes of vocational high school pupils in Indonesia are higher than conventional learning, according to 22 research studies grouped using the cooperative learning paradigm. The findings indicate that cooperative learning significantly impacts students' mathematics learning outcomes. The learning model does not address the subjectivity of the dependent variable when drawing inferences based on average outcomes for each research study result. Meta-analysis research replaces subjective judgments with objective, logical, and evidence-based findings.

Meta-analyses synthesise data from several studies on a single issue for broad generalisation. As a statistical technique, meta-analysis looks at the quantitative results of numerous research to draw broader, more general conclusions (Hunter & Schmidt, 2004; Lipsey & Wilson, 2001). Meta-analysis is a strategy for systematically reviewing empirical evidence and identifying causal links (Durlak, 1998; Rosenthal, 1991). The meta-analysis method provides the effect size by combining the data of multiple studies conducted at various dates and locations on the same issue. The meta-analysis examined data from studies comparing the impact of cooperative learning on mathematics learning outcomes of vocational high school students. Search for research articles in indexed journals SINTA and GARUDA using Google Scholar.

Meta-analysis research on the effectiveness of cooperative learning on student mathematics learning outcomes has greatly aided teachers in implementing these learning activities. The impact of the Two Stays Two Stray paradigm on student learning results (Mansurah et al., 2021) is significant. The Two Stay Two Stray style of cooperative learning also influences high school students' mathematics learning results, with an effect size of 0.445 and an appropriate measure of 0.558. The dependent variables utilized in the meta-analysis are Elementary, Junior High, and High School, and topics are Mathematics, Natural, and Social Sciences. Cooperative learning is also examined by Capar and Tarim (2015) on the dependent variable of students' mathematical abilities based on mathematics learning outcomes and attitudes toward mathematics learning. Compared to more traditional methods that focused on determining the effect size for each dependent variable, cooperative learning had a more substantial effect on students' mathematics outcomes and attitudes. Then, according to Kyndt et al. (2013), cooperative learning in science and mathematics is more effective than in social and linguistic subjects. Cooperative learning in Iran, Turkey, and other Asian countries is more effective than in the US and other EU countries. Another study by Setiana et al. (2020) found that cooperative learning has a weak influence on students' mathematics learning results across all levels of education. The meta-analysis by Agustini et al. (2021) using correlation data demonstrates that the innovative student-centred learning approach is successful on learning outcomes dependent on education level. Early childhood, junior and senior high school, and vocational high school (VHS).

Only a few studies have used meta-analysis to assess cooperative learning's impact on VHS mathematics outcomes. This study used a research study sample with the dependent variable being VHS students' mathematics learning outcomes. This study used a moderator variable based on the level and number of students in the class to determine the cooperative learning model's effectiveness on mathematics learning outcomes. Other moderator factors include Google Scholar, SINTA, and GARUDA indexed journals. The independent variable is Indonesian cooperative and traditional learning models, and the dependent variable is VHS students' mathematics learning outcomes. Sample size, mean, and standard deviation are also descriptive data analysis criteria. These findings come from experimental and control classes using the cooperative learning approach. Then, using the forest plot analysis results and a random-effects model, determine and evaluate the learning efficacy. Forest plot analysis with the Trim and Fill model is used to validate the difference in the effectiveness of the two learnings on the mathematics learning outcomes of VHS students.

Method

Research Designs

This study uses meta-analysis to discover papers that broadly and accurately relate cooperative learning to mathematics learning results for Indonesian VHS students. Meta-analysis is frequently used to combine and evaluate data from several research articles that investigate and test conceptual study topics and hypotheses (Hedges & Olkin, 1985; Glass, 1982; Lipsey & Wilson, 2001; Hunter & Schmidt, 2004). Identifying all relevant research papers, classifying those that meet the requirements, computing effect sizes, conducting statistical analysis using the effect sizes, and evaluating the results (Durlak, 1998; Höffler & Leutner, 2007). Also, other meta-analysis techniques (Card, 2012; Cooper, 2010; Borenstein et al., 2009) include defining the problem, searching the literature for relevant information, assessing the study's quality, interpreting the findings, and reporting the findings.

Research Procedure

As part of this study's meta-analysis, students from Indonesian vocational high schools were asked to rate their math teachers' effectiveness in teaching cooperative learning. Then search Google Scholar, SINTA, and the GARUDA portal for "the effectiveness of cooperative learning mathematics learning outcomes for vocational high school students" or "the effect of cooperative learning mathematics learning outcomes for vocational high school students." The following step is to gather data on research findings based on independent factors, such as the experimental group's cooperative learning model and the control group's traditional learning. The dependent variable is the VHS students' mathematics learning outcomes. The search results are then re-identified and reviewed to determine which research studies match the requirements. The identification is based on the type of research using quasi-experimental research and the availability of descriptive data analysis results, including sample size, standard deviation, and mean for both learning in the experimental and control groups. The following flow chart illustrates the procedure for finding relevant literature studies with these criteria.

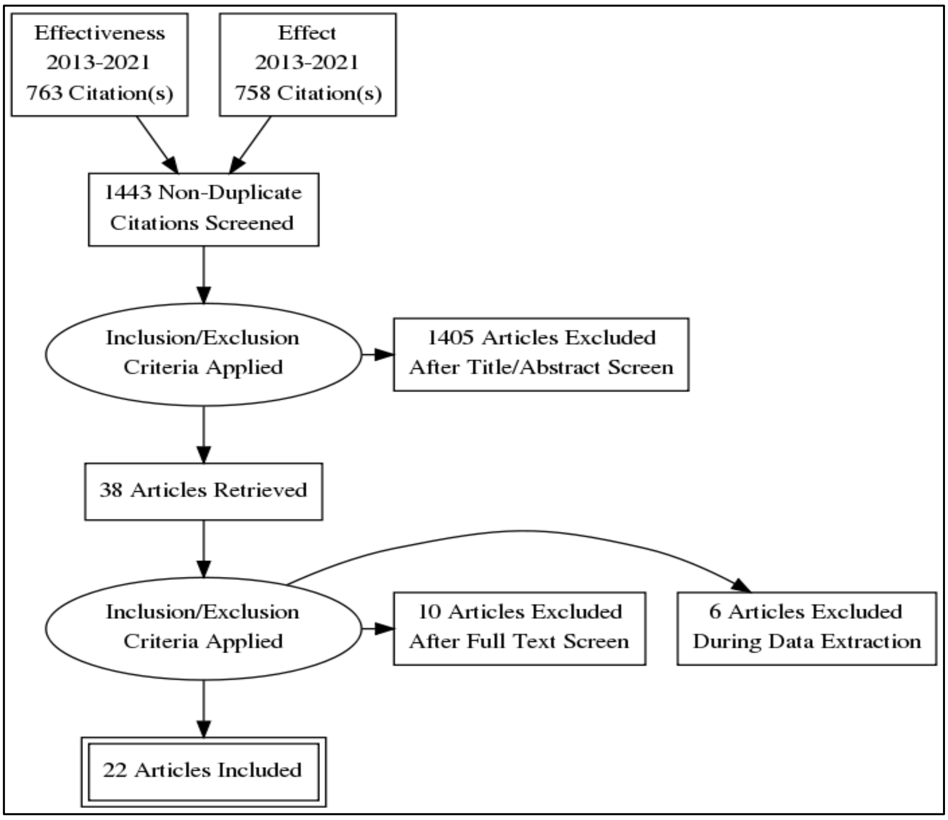


Figure 1. Flowchart of the Study Literature Search Process

The results of the study literature search procedure depicted in Figure 1 were then analysed by grouping and categorizing them according to the author's name and year of research and information data from descriptive data analysis for the two applications of the learning model. The final step in this meta-analysis is to look at studies that meet the requirements for heterogeneity, effect size calculation, forest plot, funnel plot, and publication bias.

Each research study's effect size was calculated using the heterogeneity test to identify the effect model utilised in subsequent meta-analysis. After the forest plot analysis, each sample used in the meta-analysis is given an effect size value and a summary effect size value with a lower and upper bound. Other evidence supports the finding of each research study that cooperative learning is more effective than traditional learning in increasing mathematics outcomes for VHS students. The funnel plot meta-analysis approach describes the effect size as a circle spread in a pyramid. Visually identifying the sample utilised in the meta-analysis can be done using the plot analysis results. The examination of biased publications is a step in the meta-analysis. Using funnel plots, Rank correlation and regression, and the Fail-Safe *N* technique, we could find out if there was a lot of publication bias.

Data Collection

The data were gathered through a literature evaluation that included research using cooperative learning models in the experimental class and traditional learning in the control class. Meanwhile, the dependent variable in this study is the mathematics learning outcomes of VHS students. The moderator variable in this meta-analysis research is grade 10, with 16 studies, and grade 11 learning with the rest. Other criteria are Google Scholar, GARUDA, and SINTA indexed research studies from 2013-2021. The research study criteria results were grouped and then coded based on the descriptive analysis of the two learning groups' application to the mathematics learning outcomes. It is a difference between the experimental and control groups on a measurable variable (Lipsey & Wilson, 2001). The descriptive analysis yielded sample size, mean, and standard deviation from the two learning models to assess mathematics learning results. Search the indexed journals SINTA and GARUDA using the Google Scholar search engine. The literature search yielded 22 research studies, 16 journals, and six proceedings. Some of the ten research papers used SINTA and GARUDA indexed journals, while others used Google Scholar solely indexed journals. Then the findings of descriptive data analysis based on learning in the experimental and control groups were coded with sample size, standard deviation, and mean.

Data Analysis

This study combined meta-analysis with forest plot analysis to uncover and generalise prior research findings. Studies compare successful cooperative learning effects on VHS students' arithmetic learning outcomes. Both groups are identified and validated for learning effectiveness. The forest plot technique calculates summary effect values based on the impact size of each meta-analysis sample. Determine the learning efficiency of the dependent variable by combining the estimated summary effect size and the estimated *z* value with the *p*-value. Reject the hypothesis that the effectiveness of the two learning models differs if the estimated value of *z* is less than 0.05 and the estimated summary effect size is zero (Retnawati et al., 2018). Heterogeneity testing is done before the forest plot analysis. The heterogeneity test determined if the meta-analysis utilised a random or fixed-effect model. Testing for heterogeneity can use the Q, τ^2, or I^2 parameters (Retnawati et al., 2018).

This study's heterogeneity test uses Q-statistical analysis's *p*-values, τ^2, and I^2. The heterogeneity condition means the meta-analysis data pool has multiple data distributions (Lipsey & Wilson, 2001). The heterogeneity test conditions were met if the *p*-value was smaller than the significance level. The following test employs I^2 parameter values with low, medium, and high heterogeneity levels based on the I^2 value requirements for 25% - 50%, 51% - 75%, and over 76% (Borenstein et al., 2009; Cooper & Valentine, 2009; Higgins et al., 2003). The statistical value for I^2 provides detailed information about the data distribution (Petticrew & Roberts, 2006). The parameter I^2, greater than 25%, shows much variation in the population and the size of the actual effect. It is caused by both sampling errors, the population's variability, and the size of the actual effect (Durlak, 1998; Hedges, 1983; Higgins & Thompson, 2002; Retnawati et al., 2018). Then, the DerSirmonian and Laird technique is used to estimate the value of τ^2 (Borenstein et al., 2009). The null hypothesis is rejected if the effect size between studies is more significant than zero ($\tau^2 > 0$) (Retnawati et al., 2018). The following analysis is a general validation based on a selection of previous research studies that used summary effect value data from the forest plot utilising the Trim and Fill method. Assume that the estimated summary effect value obtained using the random effects (or fixed-effects) model produced the same findings before and after applying the Trim and Fill approach. In that situation, the research on cooperative learning and mathematical learning outcomes of vocational high school students matched the criterion.

The following meta-analysis procedure employs the Trim and Fill approach to identify biased articles based on a visual funnel plot analysis (Card, 2012). Other publishing bias detection methods use statistical analyses based on funnel plots like regression (Egger et al., 1997) and rank correlation (Begg & Mazumdar, 1994). If the study has no publication bias, the funnel plot for each effect size is symmetrical (Borenstein et al., 2009; Cooper, 2016). However, if there is evidence of publishing bias, the funnel plot analysis will show an asymmetry. Then the regression approach and rank correlation using null hypothesis testing using a symmetric funnel plot. If the p-value is greater than or equal to 0.05, the funnel plot is symmetrical, with no publication bias. A p-value less than 0.05 rejects the null hypothesis, showing an asymmetrical funnel plot. The Fail-Safe N (FSN) method can help identify publication bias (Rosenthal, 1979). So that publication bias does not affect the research sample, the FSN value must be more than $5k + 10$, where k indicates the number of meta-analysed studies (Mullen et al., 2001).

Results

The literature search results revealed 22 research papers, with the research study sample criteria employed in this meta-analysis research consisting of research using quasi-experiments, the application of learning using cooperative models in the experimental class, and conventional models in the control class. The following criteria are available data from descriptive data analysis of mathematics learning outcomes based on the two-learning applications consisting of sample size, mean, and standard deviation. The meta-analysis determined the cooperative learning model's effectiveness and validity on mathematics learning outcomes for students with VHS education levels based on descriptive data analysis from each research study. The meta-analysis process includes coding data from research papers, performing a heterogeneity test, computing effect sizes, analysing forest plots, and finding publication bias. The coding of research study data aims to classify the characteristics of the data as a first step for calculating effect sizes. The second stage tests the data sample's heterogeneity that meets the criteria to determine the effect model used in the meta-analysis. The impact size calculation for each research study provides the effect size and influence of the cooperative learning model's implementation on the mathematics learning outcomes of VHS students. Using the findings of heterogeneity tests, a practical model, the forest plot summarises the impact size results from each research study's effect size. Then, for the identification phase of publication bias, the aim is to analyse the possibility that there are research study results that do not have a statistically significant effect or have a significant effect but are not by theory construction in general.

Data Encoding

The meta-analysis grouping of research findings was determined using numerical data from a descriptive data analysis of the mathematics learning outcomes of VHS students in Indonesia. The results of descriptive data analysis were derived from the experimental group's cooperative and control groups' conventional learning. This study's preliminary analysis classifies the data based on which research studies satisfied the inclusion criteria. Each study's sample size, standard deviation, and mean were used in the meta-analysis, which included the descriptive analysis of the two groups. Table 1 summarises the coding outcomes from a variety of research studies.

Table 1. Result of Data Coding

Code	Researcher and Year of Research	Experiment Group			Control Group		
		n_e	$\bar{x}_e$	s_e	n_c	$\bar{x}_c$	s_c
CL1	Ayu and Gusmania (2018)	20	81.55	11.13	14	71.79	12.21
CL2	Cahayati and Irwan (2017)	32	85.94	11.03	32	67.19	10.54
CL3	Dhema and Wahyuningsih (2018)	15	85.71	5.95	16	78.81	4.68
CL4	Dida et al. (2018)	20	81.65	8.93	19	70.92	9.21
CL5	Dunir (2019)	30	74.83	14.94	30	61.83	11.48
CL6	Ebe (2019)	32	83.84	7.48	32	74.24	6.79
CL7	Ernada et al. (2021)	20	78.65	9.71	32	69.31	10.29
CL8	Febriani et al. (2020)	34	64.50	20.56	36	61.32	15.93
CL9	Fitria and Leonard (2015)	30	17.50	2.41	30	15.90	2.26
CL10	Islami and Yondri (2016)	28	71.07	5.95	28	86.00	6.09
CL11	Natalia and Leonard (2015)	34	74.00	10.71	34	66.47	10.33
CL12	Rahayu et al. (2017)	30	20.83	3.03	30	18.23	2.80
CL13	Ramadhani and Azis (2020)	20	83.66	20.75	15	80.63	7.47
CL14	Saragih (2019)	30	79.33	7.63	30	65.33	7.98
CL15	Setiawan et al. (2020)	34	74.00	10.71	34	66.47	10.33
CL16	Setyawan and Leonard (2017)	36	73.14	14.43	35	69.74	11.09
CL17	Sudirman (2015)	20	16.00	3.32	20	13.80	5.16
CL18	Sumiati and Sumartono (2017)	40	74.16	12.37	40	61.54	11.35
CL19	Suryani et al. (2019)	29	73.45	10.12	30	66.50	9.22
CL20	Thifal et al. (2020)	32	75.28	13.54	20	66.95	15.03
CL21	Wahyuningsih et al. (2013)	29	76.00	15.07	28	55.21	19.70
CL22	Wulandari and Leonard (2015)	32	89.69	12.84	36	78.81	13.94

Note. n=sample size; $\bar{x}$= mean; s=standard deviation

The results of coding the data from the research study are summarised in Table 1. They represent the findings of a descriptive data analysis of the mathematics learning outcomes of VHS students using two distinct learning models. The experimental group engaged in cooperative learning, whereas the control group engaged in traditional learning. The results of grouping research studies based on the study literature indicate that three research studies (Fitria & Leonard, 2015; Rahayu et al., 2017; Sudirman, 2015) have averages different from the averages of other research studies. As a result, the effect size estimate in this meta-analysis study uses the Standardized Mean Difference (SMD), which is determined by dividing the difference in mean scores between the experimental and control groups by the combined standard deviation.

Heterogeneity Test

In the meta-analysis approach, heterogeneity relates to sampling error or variation in results across independent research (Borenstein et al., 2009). It was necessary to conduct the heterogeneity test to establish how much the outcome of each research study was influenced by both sampling error and the variability, or population variance, of the effect size in the study. Additionally, the heterogeneity test results determine if the study employs a random effect or a fixed effect model. Thus, the effect size or summary effect of study findings is calculated using one of these effect models for further analysis. In this work, heterogeneity testing is analysed using *Q*-statistics (with *p*-value), using the parameters I^2 and τ^2 listed in Table 2.

Table 2. The Results of the Heterogeneity Test Analysis

Dependent Variable	Heterogeneity Test Parameter				
	Q-Statistic			I^2	τ^2
	Value	*df*	*p*-value		
Mathematics learning outcomes	46.03	22	0.0020	52.2% [23.0%; 70.3%]	0.0858 [0.0196; 0.2586]

Table 2 illustrates the results of testing the heterogeneity of research papers based on mathematics learning outcomes using the statistical parameter values Q, τ^2, and I^2. The test results using the Q-statistical parameter obtained a value of 46.03 so that the value of $Q > df$ with a *p*-value of 0.0020, which is smaller than 0.05. Therefore, it may be inferred from this that the meta-analysis sample data is heterogeneous and sampling error and population variance in impact size affect research study outcome variability. The same findings were obtained to fulfil the moderate heterogeneity assumption based on the parameter value I^2 obtained 52.2%. Then the parameter τ^2 is 0.0858, which is more than zero. Additionally, it demonstrates that the effect sizes associated with each research study outcome are diverse, demonstrating heterogeneity. If the data distribution fulfils the homogeneous assumption, a fixed-effects model is employed, and if it meets the heterogeneous assumption, a random-effects model is used (Ellis, 2010). This meta-analysis study meets three criteria for heterogeneity, which means that the summaries of each research study show different effects sizes. This study employed a random-effect model to determine the extent of each study's effect and the cumulative effect based on the forest plot data.

Analysis of Effect Size Calculation

The independent factors in this study were cooperative and conventional learning approaches, while the dependent variables were VHS students' mathematical learning outcomes. Effect size analysis transformed descriptive data of students' mathematical learning results into the same measurement form. Informed by observable variables and measures, statistical analysis of effect sizes yields structured statistics with numerical information (Retnawati et al., 2018). The effect size using contrast groups is Cohen's *d* or Hedges' g (Hedges & Olkin, 1985; Cooper, 1989; Borenstein et al., 2009; Hartung et al., 2008). It was a meaningful and a purposeful act to divide the difference in the mean of each group's experimental and control groups by their combined standard deviations to get the effect sizes *d* and g (Borenstein et al., 2009). Because research findings vary in magnitude, this study's effect size analysis uses the SMD. A random-effects model adjustment factor was used to estimate the effect size g for each meta-analysed research study sample, and the findings are shown in Table 3.

Table 3. Effect Size Calculation Results

Code	SMD	95%-CI	%W (random)
CL1	0.8229	[0.1385; 1.5045]	3.45
CL2	1.7170	[1.2263; 2.2063]	4.66
CL3	1.2605	[0.5536; 1.9624]	3.34
CL4	1.1592	[0.5299; 1.7857]	3.76
CL5	0.9631	[0.4566; 1.4687]	4.54
CL6	1.3276	[0.8370; 1.8170]	4.66
CL7	0.9132	[0.3539; 1.4713]	4.19
CL8	0.1716	[-0.2972; 0.6403]	4.81
CL9	0.6760	[0.1696; 1.1817]	4.54
CL10	0.8878	[0.3769; 1.3977]	4.51
CL11	0.8797	[0.3732; 1.3853]	4.54

CL12	0.1797	[-0.4901; 0.8488]	3.53
CL13	1.7700	[1.2631; 2.2752]	4.54
CL14	0.7075	[0.2319; 1.1826]	4.76
CL15	0.2608	[-0.2045; 0.7260]	4.83
CL16	0.4970	[-0.1234; 1.1162]	3.81
CL17	1.0528	[0.6143; 1.4908]	5.03
CL18	0.7090	[0.1983; 1.2191]	4.51
CL19	0.5809	[0.0218; 1.1392]	4.19
CL20	1.1719	[0.6520; 1.6906]	4.45
CL21	0.8006	[0.3241; 1.2765]	4.75
CL22	0.9206	[0.2997; 1.5393]	3.81

An SMD analysis of Hedges *g* effect size on VHS students' mathematics learning outcomes is shown in Table 3. The significance level for calculating Hedges *g* in meta-analytical research is 95% (Borenstein et al., 2009; Hedges & Olkin, 1985). Table 3 shows the effect sizes and weights for the twenty-two empirical research studies with a lower and upper limit at the 95% significant level. Cohen et al. (2007) define weak, small, medium, and high impact sizes as 0.00 – 0.20, 0.21 – 0.50, 0.51 – 1.00, and greater than 1.01. The effect size classification shows a measure of the effectiveness of the implementation of cooperative learning in the experimental class on the mathematics learning outcomes of VHS students compared to conventional learning in the control class. The results show that for each research study it gives the same results with a positive effect size, which means that the application of cooperative learning for each research study used in the meta-analysis is effective on mathematics learning outcomes compared to conventional learning. However, each research study has a different category of effect size. Two research studies were obtained (Febriani et al., 2020; Rahayu et al., 2017), each using the Discovery and STAD (Student Team Achievement Division) learning models, which had an effect size of 0.1716 [95%-CI: -0.2972; 0.6403] and 0.1797 [95%-CI: -0.4901; 0.8488] with a weak effect size category. Then, the results of research studies by Setiawan et al. (2020) and Setyawan and Leonard (2017), respectively, using the NHT (Numbered Heads Together) and CTL (Contextual Teaching and Learning) learning models have an effect size of 0.2608 [95%-CI: -0.2045; 0.7260] and 0.4970 [95%-CI: -0.1234; 1.1162] with a small effect size category. In addition, the effect size results of the four research studies in each confidence interval contain a value of zero, which indicates a statistically insignificant effect on other research studies. The results of research studies using cooperative learning models with a medium effect size are 11 research studies. Meanwhile, the results of the other seven research studies have a high effect size, indicating that the application of the cooperative learning model is practical for the learning outcomes of VHS students compared to conventional learning. Furthermore, the results of the eighteen research studies have an effect size with a confidence interval that does not contain a value of zero, so it shows a statistically significant effect on other research studies.

Other calculations reveal that the effect size or weight of research study results affects the summary effect size, indicating that learning with a cooperative paradigm has a considerable effect on VHS students' mathematical learning outcomes. The calculation analysis results in Table 3 reveal that learning utilising the cooperative approach has a substantial effect on mathematics learning outcomes for each research study result. Sudirman (2015) discovered that the impact size area has the most prominent and substantial influence on the overall effect size, which is 5.03%. Meanwhile, the findings of Dhema and Wahyuningsih (2018) research study have the smallest area of 3.34 percent and substantially impact the summary effect size in analysing the effectiveness of cooperative learning on VHS student's mathematics learning outcomes.

Then, using the normal quantile plot in Figure 2, visualize the data distribution from the effect size analysis for the included research studies.

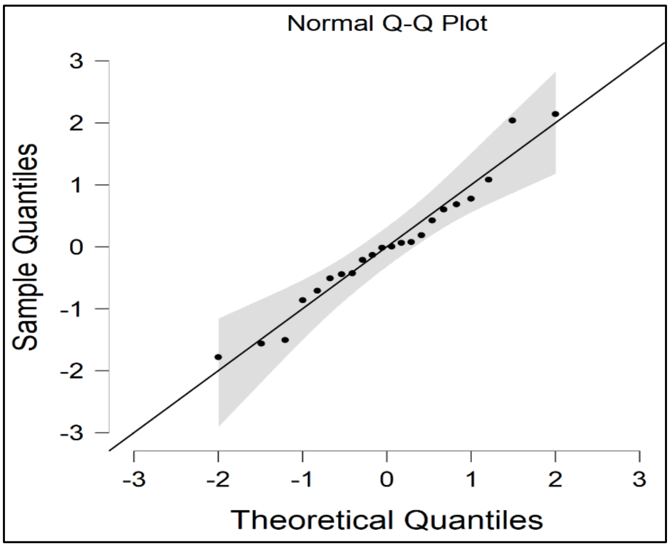


Figure 2. Result of Data Plot Based on the Effect Size Distribution

The distribution plot in Figure 2 depicts the effect size data depending on the sample of research studies included in the meta-analysis. Each research study's effect size data reveals that the data is distributed around the $y = x$ line with a 95% confidence interval. According to Rosenberg et al. (2000), the data is normally distributed if each effect size is dispersed about the line $y = x$ and contained within a 95% confidence interval. It indicates that the effect size distribution is normally distributed, with the interval between the two curving lines being normal. To discern variations in cooperative and traditional learning effectiveness on VHS students' mathematics learning outcomes, the research studies included in this meta-analysis must be statistically significant and integrated.

Analysis of Forest Plot

The forest plot analysis shows the impact of cooperative learning on VHS students' mathematics learning outcomes. Summary effect size analysis utilising forest plots and standard errors for each meta-analysis outcome. The forest plot depicts the meta-analysis findings (Borenstein et al., 2009; Card, 2012). For each research study result, a forest plot is depicted as a forest that gathers to form a forest (San & Kis, 2018). The forest plot shows effect sizes with lower and upper bounds and summary effect size information with lower and upper bounds produced from the random-effects model for each research paper. The forest plot shows a summary effect and weights for each effect size. Each meta-analysis study is shown in Figure 3 and its effect size and standard error using a forest plot analysis using the *JASP* tool.

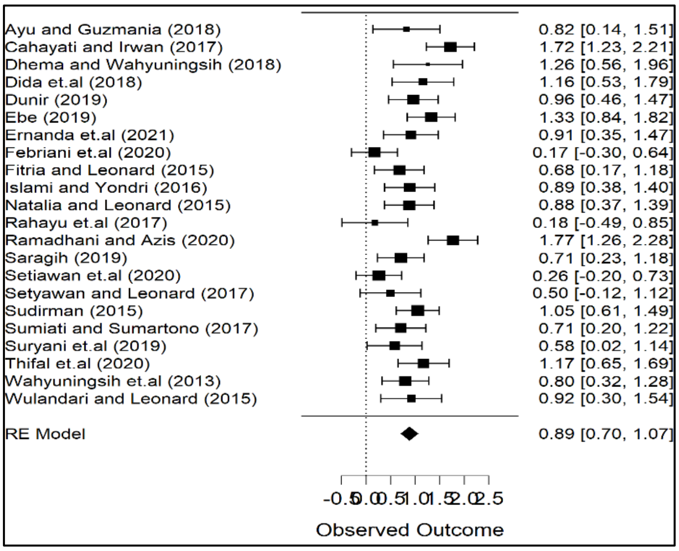


Figure 3. Forest Plot Results Based on the Random Effects Model

Figure 3 shows the results of the forest plot analysis using the random-effects model. The effect size illustrates the efficiency of cooperative learning in mathematics for VHS students. Because each research study has an effect size value greater than zero, cooperative learning has been found to help VHS students improve their mathematics scores. Figure 3 further shows that each research study sample utilised in the meta-analysis has a statistically significant effect on the overall effect size. The limiting confidence interval for each effect magnitude determines a study's suitability. The study is statistically significant if the confidence interval does not contain zero. So those 18 studies have impact sizes with confidence intervals that are not zero and hence affect the summary effect size. The effect size of other investigations (Febriani et al., 2020; Rahayu et al., 2017; Setiawan et al., 2020; Setyawan & Leonard, 2017) was also statistically inconsequential. The four research findings suggest that cooperative learning is less effective in enhancing mathematics learning results for VHS students. The forest plot also shows the summary impact size of 0.89 [0.70; 1.07], demonstrating that learning utilising the cooperative paradigm is thriving on the mathematics learning outcomes of VHS students.

Another forest plot analysis result demonstrates variations in the effectiveness of cooperative and traditional learning approaches on VHS students' mathematics learning outcomes by multiplying the estimated summary effect size value and the estimated *z*-value by the *p*-value. Table 4 shows the results of the analysis for estimating the estimated value.

Table 4. Summary of Effect Size Calculation Results

Moderator Variable		Estimate-value	95%-CI	Standard Error	*z*-value	*p*-value
All research studies		0.89	[0.70; 1.07]	0.09	9.59	< 0.001
Grade	10	0.87	[0.65; 1.09]	0.11	7.73	< 0.001
	11	0.92	[0.70; 1.14]	0.11	8.12	< 0.001
Sample Size	1-30	0.94	[0.79; 1.09]	0.08	12.21	< 0.001
	more than 30 students	0.83	[0.46; 1.19]	0.19	4.46	< 0.001
Journal Index	indexed by google scholar	0.73	[0.57; 0.89]	0.08	8.80	< 0.001
	indexed by SINTA and GARUDA	1.04	[0.74; 1.33]	0.15	6.80	< 0.001

Table 4 shows the estimated overall impact size using the random-effects model. The result of the estimated z-value was 9.59 with a p-value <0.001 (p-value <0.05) so that the hypothesis test received an estimated summary effect size value that was not equal to zero. Moderator variables including class level and student count demonstrate variations between cooperative and traditional learning on mathematics learning outcomes for VHS students. The estimated summary effect value is 0.89 [0.70; 1.07] with a 95% confidence interval. It is also statistically significant if the confidence interval contains zero. Further measurements with zero confidence intervals yielded insignificant results (Israel & Richter, 2011; Springer et al., 1999). It shows that cooperative learning improves math outcomes for vocational high school students.

The forest plot study shows that cooperative learning outperforms traditional learning in mathematics by 89%. Furthermore, the results of calculating the estimated value of the summary effect size of learning with the cooperative model on the learning outcomes of VHS students in grades 10 and 11 each gave a value of (0.87 [95%-CI: 0.65; 1.09], z-value = 7.73; p-value <0.001) and (0.92 [95%-CI: 0.70;1.14], z-value = 8.12; p-value <0.001) with p-value <0.05, respectively. These p-values demonstrate significant variations in learning efficacy in grades 10 and 11 using cooperative versus conventional approaches. Effective cooperative learning has a larger estimated summary impact size for 11th grade VHS students than 10th grade VHS students. Also, the sample size with criteria of 1-30 and more than 30 students demonstrates differences in learning efficacy with cooperative and conventional approaches. Thus, learning with cooperative models is more effective than learning with more than 30 students when the sample size is 1-30. In addition to Google Scholar, SINTA, and GARUDA index research study literature published in journals or conferences. The results of studies published in SINTA and GARUDA indexed journals estimate cooperative learning efficacy 1.04 higher than those published in Google Scholar indexed articles or conferences.

Analysis of Biased Publication

If the meta-analysis sample does not include relevant research studies, publication bias occurs (Retnawati et al., 2018). Less information and broader confidence intervals are provided by different results, which do not affect effect sizes in any way. A study's population may not be representative of the final study's population (Rothstein et al., 2005). Finding publication bias can mean finding results of statistically significant studies but do not support theory construction. According to the review, cooperative learning strategies outperform conventional learning in mathematics for VHS students. Twenty-two research articles utilising descriptive data analysis were published in journals due to applying both learning methods. On the other hand, the Fail-Safe N technique was utilised to identify publication bias.

The Trim and Fill method is a step-by-step process that removes research studies with small sample sizes that have a significant impact on the positive side of the funnel plot and recalculates the effect size for each iteration until the funnel plot is even. The funnel plot graph illustrates the effect size distribution as closed or open circles forming a funnel shape. A visual analysis of the distribution of effect sizes inside or outside the funnel identifies publications. The effect sizes are evenly distributed on both sides of the vertical line, resulting in a symmetrical presentation of the overall effect sizes. If there are studies outside the funnel, the effect is diffused in the middle and top. Publication bias is found when most research studies are spread towards the funnel plot graph's bottom or only one part of the vertical line (Borenstein et al., 2009). The effect size and standard error are used in Figure 4 as a random-effects model for each meta-analysis sample.

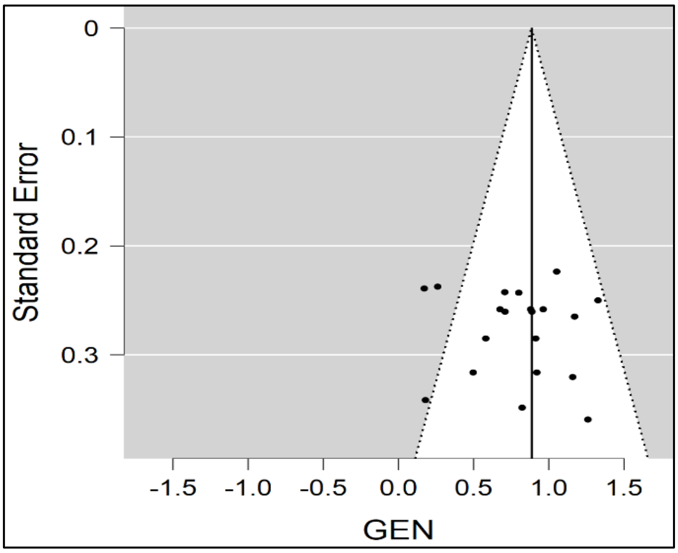


Figure 4. Funnel plot with Trim and Fill Models

As shown in Figure 4, the impact of cooperative and traditional learning strategies on VHS students' mathematics learning outcomes differed between studies. The funnel plot results in Figure 4 reveal that the effect sizes are distributed symmetrically around the vertical line. Even though there are studies with closed circles outside the funnel at the bottom and middle, the data show no publication bias. Using a funnel plot to identify biased content appears to be subjective visually. As a result, the funnel plot results are not very reliable for detecting publication bias in meta-analysis studies. Rank correlation and regression approaches and the Fail-Safe *N* method are used to build statistical tests for funnel plots in this work.

The rank correlation method aims to examine the relationship between the estimate of the intervention effect and the variance in sampling (Begg & Mazumdar, 1994), while the regression method aims to examine the linear relationship between the estimate of the intervention effect and the standard error (Egger et al., 1997). Table 5 shows the results of the calculation analysis of the two techniques using the *JASP* program.

Table 5. The Results of the Calculation Analysis using Rank Correlation and Regression Methods

Dependent Variabel	Rank Correlation Method		Regression Method	
	Correlation coefficient	*p*-value	Regression Coefficient	*p*-value
Mathematics learning outcomes	0.049	0.755	-0.213	0.831

As shown in Table 5, the meta-analysis sample utilised to assess publication bias in the cooperative learning model's impact on VHS students' mathematical learning outcomes was selected using rank correlation and regression approaches. It was 0.049 and -0.213 for both approaches, with is *p*-values larger than 0.05. Asymmetry in the funnel plot graph indicates no publishing bias based on the *p*-value. Other analyses reveal a negative regression coefficient, indicating that the meta-small analysis's sample size favors the research studies considered in this study.

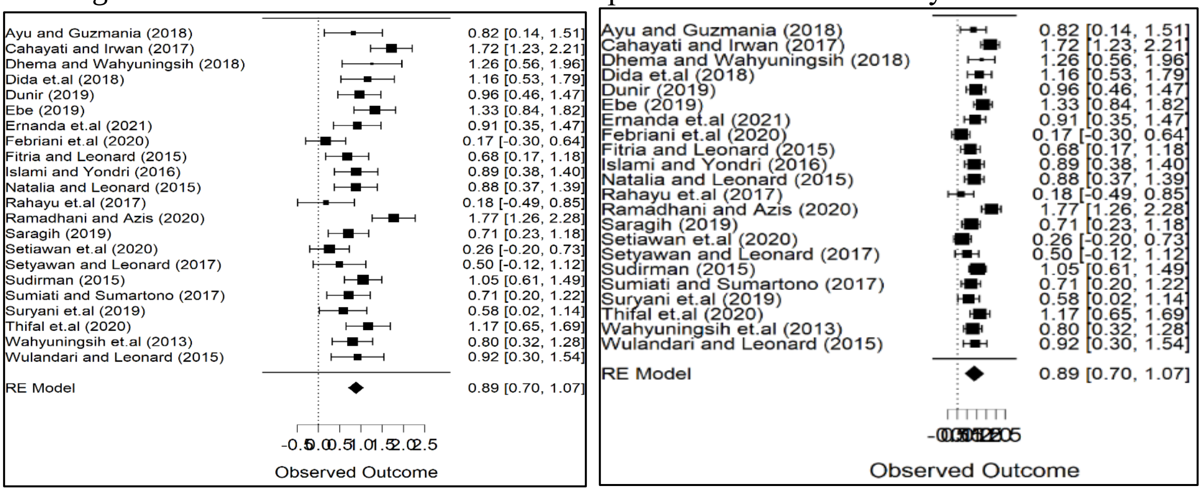
The funnel plot results can also examine the meta-analysis data's credibility. The data is normally distributed and credible if most of the impact size values are between two lines in the funnel plot (Rosenberg et al., 2000). It is seen in Figure 4 by two pyramid-shaped lines in the funnel plot graph. Two effect sizes are not on the line but in the graph. So that the meta-analysis sample data are regularly distributed and dependable. It shows that a valid meta-analysis was utilised to compare the impact of cooperative versus conventional learning in improving mathematics outcomes for VHS students.

Another publication identification used in this study is the Fail-Safe *N* method. The Fail-Safe *N* (FSN) is an approach to identify publication bias in research (Rosenthal, 1979). Suppose the FSN value is greater than $5k + 10$. The meta-analysis by Mullen et al. (2001) found no evidence of publication bias, with k being the sample size of research studies. If the meta-analysis results show publication bias, this FSN value also indicates the number of research studies added to decrease it. The value of fail-safe *N* is acquired from the following file drawer analysis utilizing *JASP* devices (see Table 6).

Table 6. Results of the File Drawer Analysis

Dependent Variabel	Fail-Safe *N*	Target Significance	Observed Significance
Mathematics learning outcomes	1885	0.050	< 0.001

According to Mullen et al. (2001), the FSN value of 1885 derived from the file drawer analysis was more than $5k + 10 = 120$ with $k = 22$. As a result, these findings indicate that the publications in this meta-analysis study are not biased. In other words, no publication bias exists in the comparison of cooperative and traditional learning in improving VHS students' mathematics outcomes. The Trim and Fill methodology is used to identify the differences in cooperative and conventional learning effectiveness in enhancing mathematics learning outcomes of VHS students. This forest plot is used to test the Trim vs. Fill model's efficiency based on the random-effects model's outputs. Figure 5 shows the plot analysis results utilizing the *JASP* tool based on the *R* tool's impact size calculation analysis.



(a) (b)

Figure 5. Forest Plot (a) Before and (b) After using Trim and Fill model

Data on effect sizes and standard errors from the meta-analysis's studies were used to generate the forest plot results shown in Figure 5. The analysis yielded effect-size values with respective lower and upper limitations for each research study and the results of summary effect size values with respective lower and upper limits. Figures 5(a) and 5(b) show the summary effect size values for the mathematical ability variable before and after Trim and Fill, providing an accurate value of 0.89 [0.70; 1.07]. It reveals that the distinction between cooperative and traditional learning is valid for boosting VHS students' mathematics learning outcomes.

Discussion

Following the meta-analysis' research study sample criteria, the literature review found 22 research papers that met the meta-analysis's sample size, mean, and standard deviation criteria. The descriptive analysis used the cooperative learning model in the experimental class and conventional learning in the control class. It was statistically significant for each research study that cooperative learning was beneficial with the cooperative approach. Cooperative and traditional learning effectiveness on mathematics learning outcomes of VHS students were reliably combined. According to Cohen et al. (2007), the cooperative learning effect size is 0.89 [95%-CI: 0.70; 1.07]. According to Kyndt et al. (2013), cooperative learning improves mathematics learning outcomes for high school pupils in an Asian country, namely Indonesia. Capar and Tarim (2015) discovered that cooperative learning has a moderate impact on mathematics learning outcomes, with an effect size of 0.59. Also, according to Turgut and Turgut (2018), the cooperative learning approach influences students' mathematics learning outcomes of 0.84 in the medium category.

Agustini et al. (2021) found that student-centred learning was superior to teacher-centred learning in early childhood, junior and senior high schools, and vocational high schools. This study used inquiry, cooperative, and technology-based learning approaches. The findings indicated that cooperative learning had a significant effect on student outcomes. Then, Mansurah et al. (2021) found that the Two Stay Two Stray cooperative learning paradigm affects high school students' mathematics learning outcomes. Cooperative learning has a negligible effect of 0.445 in mathematics courses and a medium effect of 0.558 in high school. The same meta-analysis review found a 0.15 measure of the effectiveness of cooperative learning on students' mathematics learning outcomes (Setiana et al., 2020). The effect size of cooperative learning on students' cognitive capacities is 1.213 in the strong category (Alacapınar & Uysal, 2020). The study focused on pupils' mathematical learning outcomes rather than cognitive aptitude.

Cooperative learning is also evaluated in terms of its impact on mathematics learning outcomes by using moderator variables such as grade level and class size. The estimated effect size of the learning summary with the cooperative model on the learning outcomes of VHS students in grades 10 and 11 was 0.87 [95%-CI: 0.65; 1.09]. The results show that cooperative learning is more effective in 11th-grade mathematics than in 10th-grade mathematics. Then, the effectiveness of learning using the cooperative model on VHS student learning outcomes dependent on class size was 0.94 [95%-CI: 0.79; 1.09] and 0.83 [95 %-CI: 0.46; 1.19]. The results show that learning with a cooperative approach is more effective than studying with a large group of students (1-30). Other research shows that grouping research articles published in SINTA and GARUDA-indexed journals have an appropriate measure of 1.04, higher than grouping papers published in Google Scholar-indexed journals or proceedings. The meta-analysis review is only based on the variables of education level, the field of study, culture, the field of mathematics, cooperative learning techniques used, and duration of mathematics learning (Agustini et al., 2021; Capar & Tarim, 2015; Kyndt et al., 2013; Mansurah et al., 2021; Setiana et al., 2020; Turgut & Turgut, 2018) and based on cognitive, affective, and psychomotor abilities (Alacapınar & Uysal, 2020).

Kyndt et al. (2013) employed moderator variables based on education level, study field, and culture. The meta-analysis shows that cooperative learning affects all stages of education, albeit it affects secondary education less than elementary and college. The summary effect size of cooperative learning in elementary school was not substantially different from that in secondary school. The cooperative learning paradigm also reveals considerable variances between variables. Cooperative learning in science and mathematics has a more significant aggregate effect than social and linguistic domains. Cooperative learning in Iran, Turkey, and Asian countries has a more significant summary effect than cooperative learning in the US and other EU countries. Capar and Tarim (2015) employed student ability as the dependent variable with moderator variables based on learning outcomes in mathematics, education level, mathematics field, cooperative learning approaches used, and duration of learning mathematics. The cooperative approach is most effective at the tertiary level, with an impact size of 1.33, and at the high school level, with a 0.54.

Turgut and Turgut (2018) used four criteria for moderating variables to identify the effect of cooperative learning models on mathematics learning outcomes. The study's moderator factors were cooperative learning strategies, education level, learning domain, and learning time. Results demonstrated that cooperative learning did not influence mathematics learning outcomes at any level of schooling (elementary through post-secondary). Mansurah et al. (2021) used moderator variables of elementary, junior high, and high school levels. Subject variables include mathematics, natural sciences, and social sciences. The results suggest that Two Stay Two Stray cooperative learning has an effect size of 0.445 and an appropriate measure of 0.558 on high school mathematics learning outcomes. Setiana et al. (2020) revealed that cooperative learning has a weak effect on students' mathematics learning outcomes. The meta-analysis research by Agustini et al. (2021) employing correlation data reveals that the innovative student-centred learning model significantly enhances learning outcomes for different levels of education. Early childhood education, junior and senior high schools and vocational high schools are available. Inquiry, cooperative, and technology-based learning are examples of innovative learning. Students are the centre of activity in the cooperative learning approach, which has high efficacy measures on learning outcomes. Weaknesses in this study using the dependent variable consisting of learning outcomes in general based on learning achievement, critical thinking skills, and other abilities. In order to assess the success of student-centered creative learning, the dependent variable might be grouped depending on moderator variables. It is possible to acquire research results utilising other moderator variables such as grade level.

The meta-analysis comparing the efficiency of learning with cooperative models on the mathematics learning outcomes of VHS students also discovered publication bias based on the results of 22 research publications. Visual analysis of funnel plot results utilising Trim and Fill, rank correlation and regression, and the Fail-Safe *N* technique. Figure 4 shows that the effect sizes are symmetrically spread around the vertical line. Even though there are studies with closed circles outside the pyramid at the bottom and middle, the data show no publication bias. The judgment appears subjective due to the visual identification of biased publications using the funnel plot. So the forest plot results do not give strong evidence of publication bias in the meta-analysis studies. Thus, this study's publication bias detection uses Rank correlation, regression, and the Fail-Safe *N* approach for funnel plots. The calculated correlation and regression coefficients were 0.049 and -0.213, with *p*-values larger than 0.05. The results show that detecting publications using Rank correlation and regression approaches do not result in publication bias. The funnel plot results can also be used to assess the reliability of the meta-analysis data. Graphs like Figure 4 illustrate that most effect size values are between two pyramid-shaped lines. In the graph's but two effect sizes are outside these lines. So, according to Rosenberg et al. (2000), the meta-analysis sample data was normally distributed and credible. The meta-analysis sample has no publication bias when using the Fail-Safe *N* method to locate other studies.

A review of meta-analysis to identify measures of the effectiveness of cooperative learning models on student learning outcomes has been carried out by Agustini et al. (2021), Alacapınar and Uysal (2020), Capar and Tarim (2015), Kyndt et al. (2013), Mansurah et al. (2021), Setiana et al. (2020), and Turgut and Turgut (2018). It is just that the research procedure to identify publication bias based on a sample of research studies related to the effectiveness of the learning was carried out by Alacapınar and Uysal (2020), Mansurah et al. (2021), and Setiana et al. (2020). The study results by Mansurah et al. (2021) identified publication bias using funnel plot analysis based solely on the identification of open and closed circles. Then, research by Setiana et al. (2020) using funnel plot analysis and Rank and Regression correlation methods. Using the Trim and Fill models, a funnel plot analysis was carried out visually, with the outcomes of the plots compared before and after the models were applied. As for the regression and rank correlation methods, the regression and correlation coefficients were 0.683 and 0.247, respectively, with a *p*-value greater than 0.05. The findings revealed that the research studies utilised in the meta-analysis had no publication bias. Then, the study by Alacapınar and Uysal (2020) used visual funnel plot analysis to test the heterogeneity of the effect size data distribution for each research study used in the meta-analysis. In the meantime, the forest plot results were simply utilised to describe the impact size results for each research study, and the summary effect size results were calculated using cognitive, affective, and psychomotor abilities. As for the limitations in the research conducted for each of the researchers above, they did not carry out testing procedures for the distribution and reliability of effect size data based on the research study sample used in the meta-analysis. An analysis of all the research papers in a meta-analysis can use a reliability test to figure out how reliable the data in those papers are. It affects how significant the total effect size value is.

A meta-analysis approach was used to identify and validate the grouping of results from research studies related to learning effectiveness with an effective cooperative model on VHS students' mathematics learning outcomes. The second contribution is the identification of biased publications through the use of the Trim and Fill approach to the meta-analysis sample's study data. This meta-analysis approach analyses and tests the same conceptual research issues and hypotheses based on published relevant research data. Difficult to measure characteristics, general theory construction, and research findings expectations are some other classifications used to inform readers about investigations.

Conclusion

This study's meta-analysis shows that cooperative learning improves mathematics learning outcomes for VHS students. Students collaborate in small groups to help each other understand the material. The cooperative approach's effectiveness on students' mathematical learning outcomes in grades 10 and 11 is 0.87 and 0.92, respectively. It reveals that using the cooperative learning model improved mathematics learning results for 11th-grade VHS students by 92%. The cooperative model also yields an impact size based on class size, 0.94 for 1-30 students and 0.83 for 30 or more students. This study's findings help teachers adapt cooperative learning strategies to VHS students in grades 10 and 11 to improve mathematics learning outcomes. A measure of the effectiveness of cooperative learning was also produced, which was 1.04 greater than results of studies published in journals or sessions indexed by

Google Scholar. The findings of research investigations in indexed journals SINTA and GARUDA reveal statistically significant effects by theory creation in general. The study's limitations are the grouping of research studies conducted in Indonesia and the descriptive data analysis of research papers used in the meta-analysis published in journals indexed by Google Scholar, GARUDA, and SINTA. Therefore, recommendations for further research use the results of research studies by considering the international scope to provide information to teachers widely in other countries. As an additional measure for journal credibility, the research findings published in journals or seminars that Scopus or other recognised indexers index are considered when categorising literature studies. These results can provide different information on the results of the application of cooperative learning to improve student learning outcomes by theoretical construction in general.

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An asterisk (*) indicates the research findings used in this meta-analysis study.

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