

The Relationship between Problem-Solving Skills and Student Academic Achievement: A Meta-Analysis in Education

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Abstract

The use of meta-analysis allows the results obtained to be representative, and meta-analysis of the correlation between problem-solving skills and students' learning outcomes and/or achievements is no exception. Problem-solving skills are very important for students in various learning contexts. This study aims to describe the relationship and effects of problem-solving skills on learning outcomes and or student achievement. This study used a descriptive quantitative method using meta-analysis that focuses on the relationship between two or more variables. The meta-analysis was conducted on 22 articles selected from the screening of articles from 2008-2023 in the SINTA (Science and Technology Index) and Garuda (Garba Rujukan Digital) databases. The results showed that the impact of problem-solving ability on learning outcomes and achievement was very significant at 84.8%. There is a strong positive correlation ($r = 0.69$) between problem-solving ability and student learning outcomes and/or achievement. The distribution of studies in this meta-analysis is relatively symmetrical, and there is no publication bias. Nonetheless, it is necessary to consider potential sources of heterogeneity when applying these findings to educational practice.

Keywords: *Problem-solving skills, learning outcomes, achievement, learners, meta-analysis.*

Introduction

Problem-solving ability is an essential skill that involves a wide range of cognitive functions and plays an important role in many fields, including business, education, and science (Choudhar et al., 2022; Maharani & Mahmudi, 2022; Prescott, Gruber, Olson, 1987; Yuristia & Musdi, 2020). In the dynamic and complex world of education, problem-solving is a key skill in developing learners' abilities (Redding, 2014). Problem-solving ability is part of the competencies and skills that students need to have in the 21st century (Wagner, 2014). The 21st century requires human resources who have the ability to compete and a variety of skills (Ramdani et al., 2019). Problem-solving ability is defined as a cognitive process within a person to overcome a problem that does not have an immediate or obvious solution (Jonassen, 2006). These skills enable individuals to identify and address the source causes of problems, think analytically and creatively, and make effective decisions (Choudhar et al., 2022). With possession of these skills, individuals can support communication, confidence, and the ability to transfer knowledge to different environments (Wismath et al., 2014). Problem-solving ability is positively correlated with critical thinking ability. The higher the problem-solving ability, the higher the critical thinking ability, and vice versa (Susilowati et al., 2020). These skills need to be practiced in order to improve an individual's ability to cope with problems (Spaccarelli et al., 1992), and the importance of a teacher in fostering these skills (Mukhopadhyay, 2013). Therefore, in learning, teachers need to facilitate the growth and development of this ability for all students.

Learning is the process of students' interaction with educators and learning resources in a learning environment. The use of various learning strategies by teachers is an effort to activate students in order to obtain learning experiences and learning outcomes. Hopefully, the learning experiences and results obtained by students are balanced and consist of a combination of cognitive, affective, and psychomotor aspects (A. W. & Banawi & Banawi, 2014). Learning outcomes are used by teachers as a measure or criterion for achieving an educational goal. This can be achieved if students understand learning, which is accompanied

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by changes in behavior for the better. Learning achievement is the result that students achieve in their learning efforts, which can be seen from the grades they get (Pratiwi et al., 2018).

The relationship between problem-solving ability and learning outcomes and or student achievement needs to be known. By knowing the relationship between two or more variables, the form of the relationship (symmetrical, causal, or interactive) can be known (Sugiyono, 2006, p. 210). As we all know, the learning process and results can be influenced by internal and external factors (Purwanto, 1990, p. 70). Quality learning can be realised if the learning places teachers according to the needs of students in learning (Wibowo & Hamrin, 2012). By knowing the relationship between problem-solving ability and learning outcomes and or learning achievement, preliminary data will be obtained as diagnostic and reflective material. Diagnostic results in teaching can be used to help teachers recognize and facilitate learning needs and improve students' learning (LaFrance, 1994). The data obtained will provide information on ways or solutions to strengthen and improve problem-solving skills because this ability needs to be possessed by all students. Improving students' ability in problem-solving skills will have a good influence on learning at school and produce good learning outcomes; it is also expected to improve the learning achievement of Indonesian students (Suryana et al., 2022). To find out the relationship between problem-solving skills and learning outcomes and or student achievement in the Indonesian context, a meta-analysis needs to be conducted. Meta-analysis is used to determine the impact of various learning approaches that have been carried out on learning outcomes. Meta-analysis is a growing method that has progressed in recent years, expanding the effectiveness and accuracy of the results (Paul & Barari, 2022), and is a statistical method for analyzing data from various pre-existing studies (Glass, 1976).

The use of meta-analysis in research is not new. However, the study in this research is not similar to the existing ones. Some relevant and existing research studies can be used as initial and complementary clues in conducting the study and discussion (Banawi et al., 2023). New research is expected to develop previous findings in order to contribute to the formation and development of knowledge in the research domain (Grewal et al., 2018). Furthermore, no reports have been found on the results of meta-analyses of the correlation of problem-solving skills with learning outcomes and or student achievement, supporting the need for this paper to be made. It is hoped that through the use of meta-analysis and the evidence it produces, more accurate conclusions, detection of true effects, representative subjects, clinical practice efforts and policy support, and new studies or future research directions will be obtained (Anwar, 2005; Mansyur & Iskandar, 2017). Moreover, it will provide insights for decision-making in the development of education that focuses on improving this skill domain.

Research Question

The purpose of the meta-analysis research is to collect and analyze data from several previous studies related to problem-solving ability and learning outcomes and/or student learning achievement in the context of education in Indonesia.

The research questions are as follows.

1. What is the effect size value of all studies and the correlation value of all studies?
2. Is there publication bias in all studies?
3. Identify which school levels were heavily scrutinized in all studies?

Methods

This type of research is quantitative research with a correlation meta-analysis approach, focusing on correlational relationships between two or more variables. Typically, this research involves collecting data from a variety of previously conducted studies that investigate the relationship between specific variables (Guzzo et al., 1987; Retnawati et al., 2018; Schulze, 2004): (1) Determination of effect size, (2) Fisher's

Transform, (3) Calculating summary effect and heterogeneity, (4) Convert Result to correlation coefficient (r), and (5) Interpretation of results and reporting.

Literature Search

The first step before conducting the meta-analysis was a literature search. The literature search was conducted with the help of computers and hand searching. This activity focused on problem-solving skills and student learning outcomes or achievements in Indonesia. Literature sources came from journal databases indexed by SINTA (Science and Technology Index) and Garuda (Garba Rujukan Digital). SINTA and Garuda are two scientific article indexing platforms used in Indonesia. Both platforms serve to index scientific works such as journals, conferences, and other publications from Indonesian researchers and aim to increase the accessibility and visibility of research conducted by researchers and academics. SINTA and Garuda were chosen because they guarantee the quality of the literature data to be analyzed and consider the development trend of students' problem-solving ability and learning outcomes. The literature search process was limited to literature published from 2008-2023. From the Google Scholar data search using keywords (problem-solving ability, student learning outcomes, and student learning achievement), 500 pieces of literature were obtained. This consists of 350 pieces of literature from SINTA and 150 pieces from Garuda. The literature search and screening process is summarised in Figure 1 below.

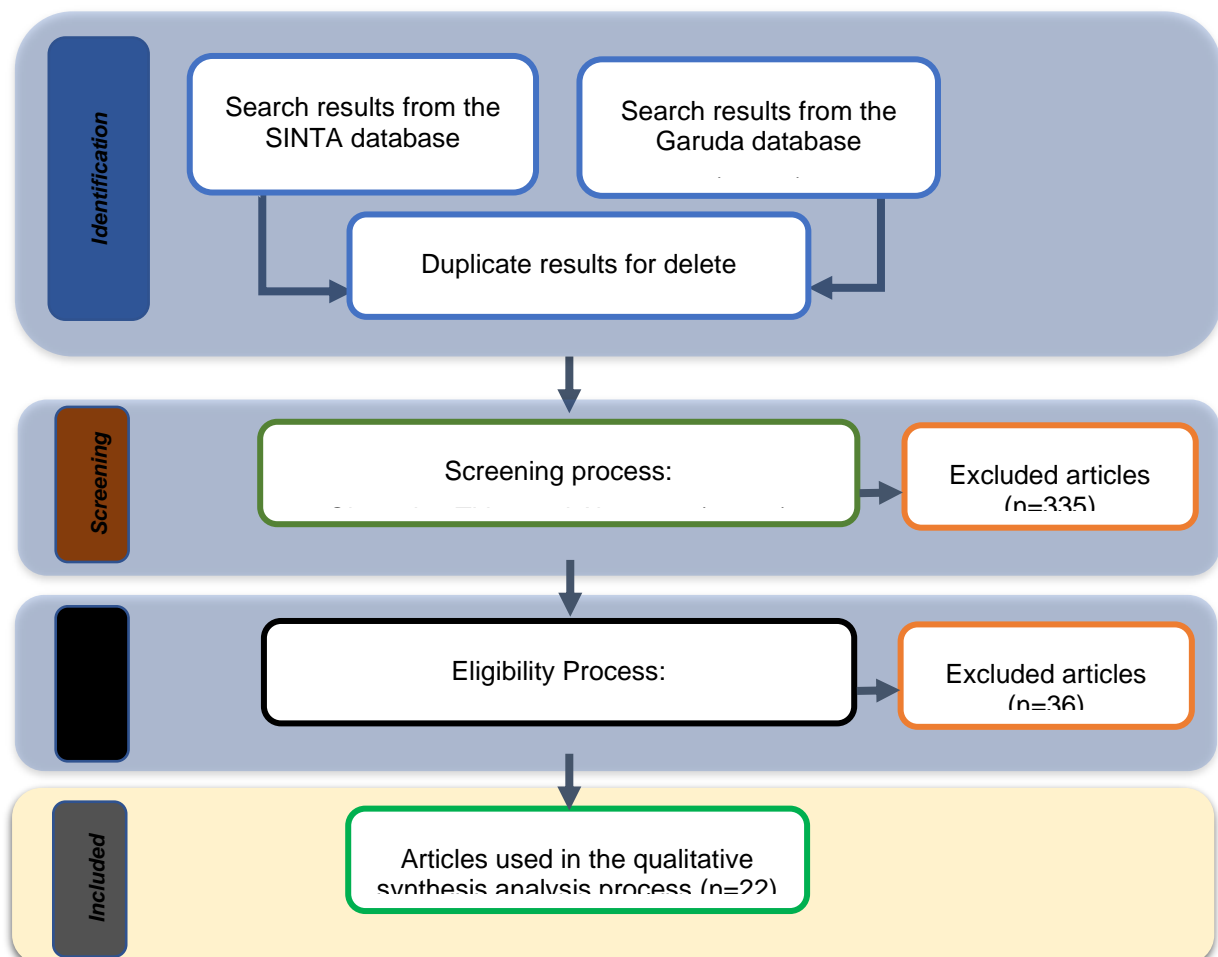


Figure 1: Literature search and screening process

Data Collection

The articles that were collected were filtered according to predetermined criteria and quality. Data collection in this study used databases on SINTA and Garuda, and 22 articles were relevant for meta-analysis. Relevant articles were taken in the last ten years and have fulfilled the article adequacy aspect in the meta-analysis because there are more than ten articles (Schmidt & Hunter, 2016). The data for this study are presented in Table 1 below.

Table 1. Research Data Tabulation

No	Author, Year	N	t	F	r	Grade
1	(Suhendri, 2015)	40		5.611		Elementary school
2	(Eftafiyana et al., 2018)	34			0,621	Junior high school
3	(Tamsik Udin, 2012)	45	6.86			Elementary school
4	(Annet & Naranjo, 2014)	31			2,779	Junior high school
5	(Amalia et al., 2018)	32			0,804	Junior high school
6	(Supardi & Putri, 2011)	13			0,573	Senior high school
7	(Yulistiana, 2015)	28			0,782	Senior high school
8	(Kumalawati, 2015)	12			0,409	Junior high school
9	(Ambiyar et al., 2020)	30			0,78	Senior high school
10	(Sagita, 2017)	21			0,70	Elementary school
11	(Fai'q Unaifah, 2014)	12			0,32	Senior high school
12	(Hartati et al., 2020)	198			0,74	Senior high school
13	(Markawi, 2015)	100	2,98			Senior high school
14	(Manalu et al., 2023)	30			0,517	Junior high school
15	(Kusumawati, 2017)	32		4,10		Junior high school
16	(Ansori & Herdiman, 2019)	27			0,80	Junior high school
17	(Sagita et al., 2018)	27			0,70	Elementary school
18	(Asiyah et al., 2021)	26	3,4			Senior high school
19	(Novita, 2015)	30			0,76	Junior high school
20	(Linda, 2022)	43	4,71			Elementary school
21	(Giyanti & Sari, 2022)	96			0,74	Senior high school
22	(Kusuma, 2021)	36			0,86	Senior high school

Data Analysis

JASP (Jeffreys's Amazing Statistics Program) assisted correlation analysis was used for data analysis. JASP is a statistical software (free and open-source) designed to perform statistical analyses intuitively and more easily than some other software (such as SPSS, R, or SAS). JASP offers an easy-to-understand and convenient user interface. This makes it popular among academics, researchers, and students who may not have a strong statistical background. Statistical data analysis in this paper includes homogeneity test and Overall analysis.

Result and Discussion

Homogeneity Test

In meta-analysis, homogeneity of effect size is an indicator that the results of the pooled studies are statistically consistent with each other. Homogeneity means that variation between study results can be reasonably attributed to random sampling error alone rather than to substantial differences in study design, population, intervention, or outcome measurement. The homogeneity of effect size can be tested using Q and I^2 statistics.

Tabel 2. Fixed and Random Effects

	Q	df	p
Omnibus test of Model Coefficients	97.567	1	< .001
Test of Residual Heterogeneity	124.143	21	< .001

Note. *p* -values are approximate.

Note. The model was estimated using the Maximum Likelihood method.

In Table 2, it is noted that the *Q* value (124.143) > 32.67 ($\alpha = 0.05$, $df = 22$), which means that the effect size between studies is heterogeneous. In other words, all studies included in the meta-analysis essentially estimated different effects. Using *Q*, the effect size deviation index I^2 can be calculated.

	Estimate
τ^2	0.132
Γ	0.363
I^2 (%)	83.290
H^2	5.984

Table 3 shows that the I^2 value is 83.290 (or about 83%). This suggests that most of the variation between the results of the studies included in the analysis is due to true heterogeneity rather than random sampling error. In other words, 83% of the variation in effect size cannot be explained by chance alone or very substantial heterogeneity. This indicates that researchers should not be hasty in interpreting the results of the meta-analysis and may need to consider looking for the source of the heterogeneity. Sources of heterogeneity could stem from differences in study population characteristics, differences in study design or implementation, differences in outcome measurement, or other factors. It is important to identify and understand the sources of heterogeneity as this may determine the generalisability of the results. Researchers may need to conduct subgroup analyses or sensitivity analyses, as mentioned, to explore and possibly explain the source of such heterogeneity.

Furthermore, the significance of the correlation between problem-solving ability and learning outcomes or learning achievement using the random effects model can be determined from the *p*-value.

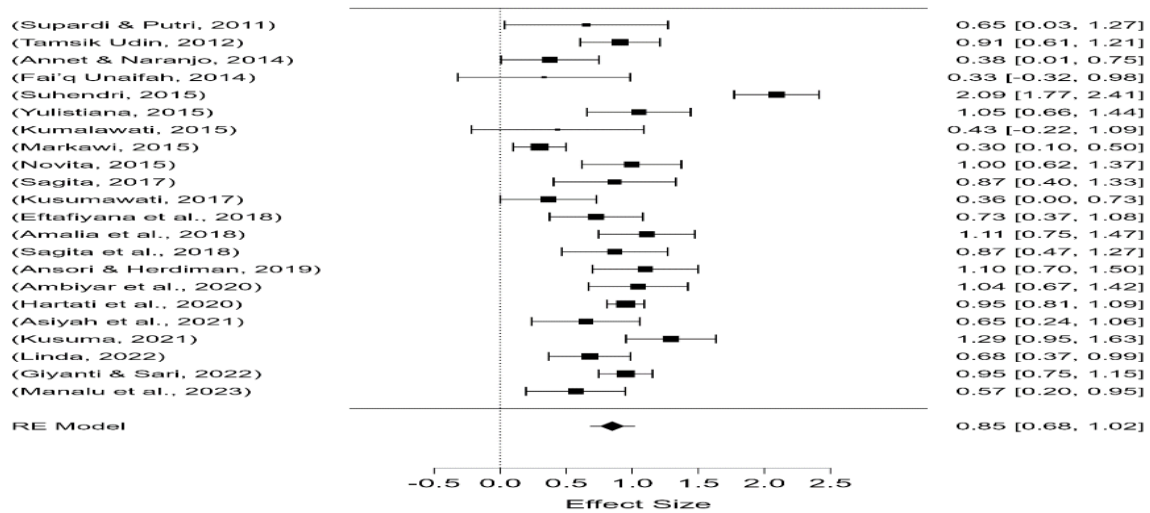
Estimate	Standard Error	z	p
intercept 0.848	0.088	9.653	< .001

Note. Wald test.

From the analysis, the *z* value is 1.371, then the *z* value is substituted using a one-tailed test, then $p = 1 - \Phi(9.653) = 0.00$. If the two-tailed test is used, then $p = 2[1 - \Phi(9.653)] = 0.00$. The *z* value = 9.653 with a *p*-value < 0.05, as shown in Table 4. Based on the random-effects model, this indicates that there is a difference in problem-solving ability with learning outcomes or student achievement. The results are considered statistically significant, and the observed findings reflect real patterns or effects in the data rather than mere chance or random variation. The impact of problem-solving ability on learning outcomes or achievement is highly significant at 84.8%.

Several previous studies have shown the same thing, consistently showing a positive correlation between problem-solving skills and student learning outcomes. Problem-based learning significantly improves learning outcomes and problem-solving skills (Syarifuddin et al., 2023). Other research shows the effectiveness of problem-solving teaching techniques in developing higher-order learning outcomes (G. L. Sharma, 2000). Further other research supporting these findings shows that problem-solving-based learning environments improve students' problem-solving skills (Karatas & Baki, 2013). Teaching problem-solving skills has an impact on educational progress and students' self-education concepts (Zera'at & Ghafourian,

2009). These studies collectively show that problem-solving skills play an important role in improving student learning outcomes. Furthermore, graphs of the results of some of the studies included in the analysis need to be displayed. In a meta-analysis, the commonly used graphical analysis is the Forest Plot. Each bar in the forest plot represents one study, with the length of the bar indicating the confidence interval for the estimated effect of that study and the vertical line in the center of each bar representing the point value of the effect. The Forest Plot (see Figure 2) visualizes the results of the studies included in the meta-analysis.



Gambar 2. Forest Plot

The figure above shows that both the common effect model and the Random Effects Model are positively correlated with 0.85 with intervals [0.68; 1.02], then determine correlation coefficient, based on the heterogeneity test above, the model chosen is the Random effects model, then

$$r = \frac{e^{2(0,85)} - 1}{e^{2(0,85)} + 1}$$

$$r = 0,69$$

Thus, the conversion interval is as follows:

$$LL_r = \frac{e^{2(0,68)} - 1}{e^{2(0,68)} + 1}$$

$$LL_r = 0,59$$

And

$$UL_r = \frac{e^{2(1,02)} - 1}{e^{2(1,02)} + 1}$$

$$UL_r = 0,77$$

The value of $r = 0.69$ with the interval [0.59; 0.77] is an indicator that there is a strong and significant correlation between problem-solving ability and student learning outcomes. An effect estimate of 0.85 can indicate how well an intervention or independent variable studied improves problem-solving ability in the

population under study. Lower (0.68) to higher (1.02) confidence intervals indicate how widely the effect may vary in the wider population.

In the context of learning outcomes, a value of 0.85 indicates how much change is expected in learning outcomes as a result of the independent variable under study. A wide confidence interval may indicate significant variation in the impact of that variable on learning outcomes or the presence of other factors that influence the relationship between that variable and learning outcomes. Thus, 22 studies on problem-solving ability and student learning outcomes show that the impact of problem-solving ability can help students in solving various problems in learning. Several studies have consistently shown that problem-solving skills are essential for students in a variety of learning contexts. Secondary school students' problem-solving skills in science are low, indicating a need to improve learning activities (Riznani & Siahaan, 2019). The role of problem-solving in building new scientific knowledge and the importance of a teacher in fostering this skill (Mukhopadhyay, 2013). There is a need for students to develop appropriate problem-solving strategies, especially for non-routine problems (Belgin Bal İncebacak & Esen Ersoy, 2016). These studies collectively underscore the importance of problem-solving skills in enhancing students' learning experience.

Biased Publication

The impact of publication bias is that the results or information produced are inaccurate, as the published literature may not be representative of the research that has been conducted on a topic. The publication bias analysis of 22 studies on problem-solving skills and learning outcomes is as follows.

a) Funnel Plot

Traditionally, the Funnel Plot is plotted from the effect size on the X-axis and the sample size or variance on the Y-axis. The publication bias analysis with the Funnel Plot approach is presented in Figure 3 below.

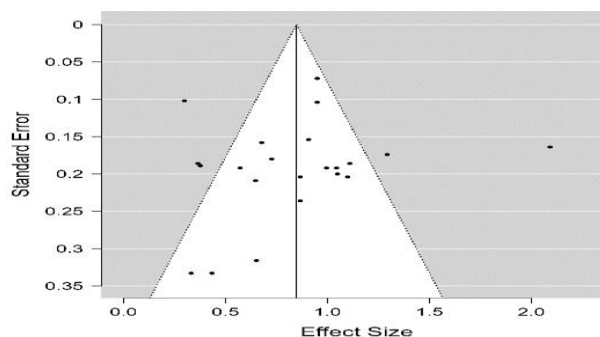


Figure 3. Funnel Plot

Figure 3 is a funnel plot with the fixed-effects model showing that of the twenty-two studies sampled in the meta-analysis, the average study had an even sample size from small to large. If we look closely, the twenty-two studies are symmetrically distributed. This implies that there is no potential for publication bias.

b) Rank Correlation and Regression Method

The rank correlation and regression method is a statistical test development of the funnel plot. The rank correlation itself was proposed by Begg and Mazumdar, which aims to test the relationship between the estimate of the intervention effect and the sampling variance (Begg & Mazumdar, 1994). The regression method proposed by Egger, Smith, Schneider, & Minder aims to test the linear relationship between the estimate of the intervention effect and its standard error (Egger et al., 1997). Generally, the regression method is stronger than rank correlation (Rothstein et al., 2005). The second null hypothesis is that the funnel plot is not asymmetric. If the two-sided p -value $< \alpha$, then the null hypothesis is rejected, or in other

words, the funnel plot is symmetrical (no publication bias). For the purpose of a statistical test of the funnel plot, JASP 0.18.1 software is used; the summary of the analysis results is shown in Table 5 below.

Table 5. Hasil Rank Correlation dan Regression dari Funnel Plot

Meta-analysis	Metode Rank Correlation		Regression Method	
Problem-solving skills and learning outcomes	P-Value	Rank Correlation	P-Value	Rank Correlation
	0,224	-0,189	0,345	-0,945

Table 5 shows that the p-value for both methods (rank correlation and regression) is greater than α (0.05). This indicates that the funnel plot formed from the fixed-effects model in the twenty-two studies is symmetrical, or in other words, there is no evidence of publication bias. The negative rank correlation (-0.189) indicates that the inverse relationship between the two variables under study is more dominant in studies with large sample sizes. A regression coefficient of -0.945 in the context of meta-analysis, particularly when discussing publication bias, refers to the result of a regression model that aims to assess the effect of sample size or other characteristics of the study on the reported effect size. If this regression coefficient is derived from a regression model testing the relationship between effect size and sample size (or vice versa), a negative value indicates an inverse relationship. A significant negative coefficient in analyses, such as Egger's linear regression to detect publication bias, could indicate the presence of publication bias. Studies with larger effect sizes (positive or negative) may be more likely to be published or easier to find in literature searches, especially if they have smaller sample sizes and, therefore, higher variance in the effect size estimates. Thus, as in the funnel plot method, it is also concluded that there is no publication bias.

c) Trim and Fill

Trim and Fill use an iterative procedure to remove the most extreme small studies from the positive side of the funnel plot, recalculating the effect size at each iteration until the funnel plot is symmetrical. In theory, this should result in an unbiased effect size estimate. In addition to this trim resulting in an adjusted effect size, it also reduces the variance of the effect and results in a narrower confidence interval. Therefore, it is necessary to add the original study back into the analysis. The fill has no impact on the point estimate but serves to correct the variance (Duval & Tweedie, 2000b, 2000a).

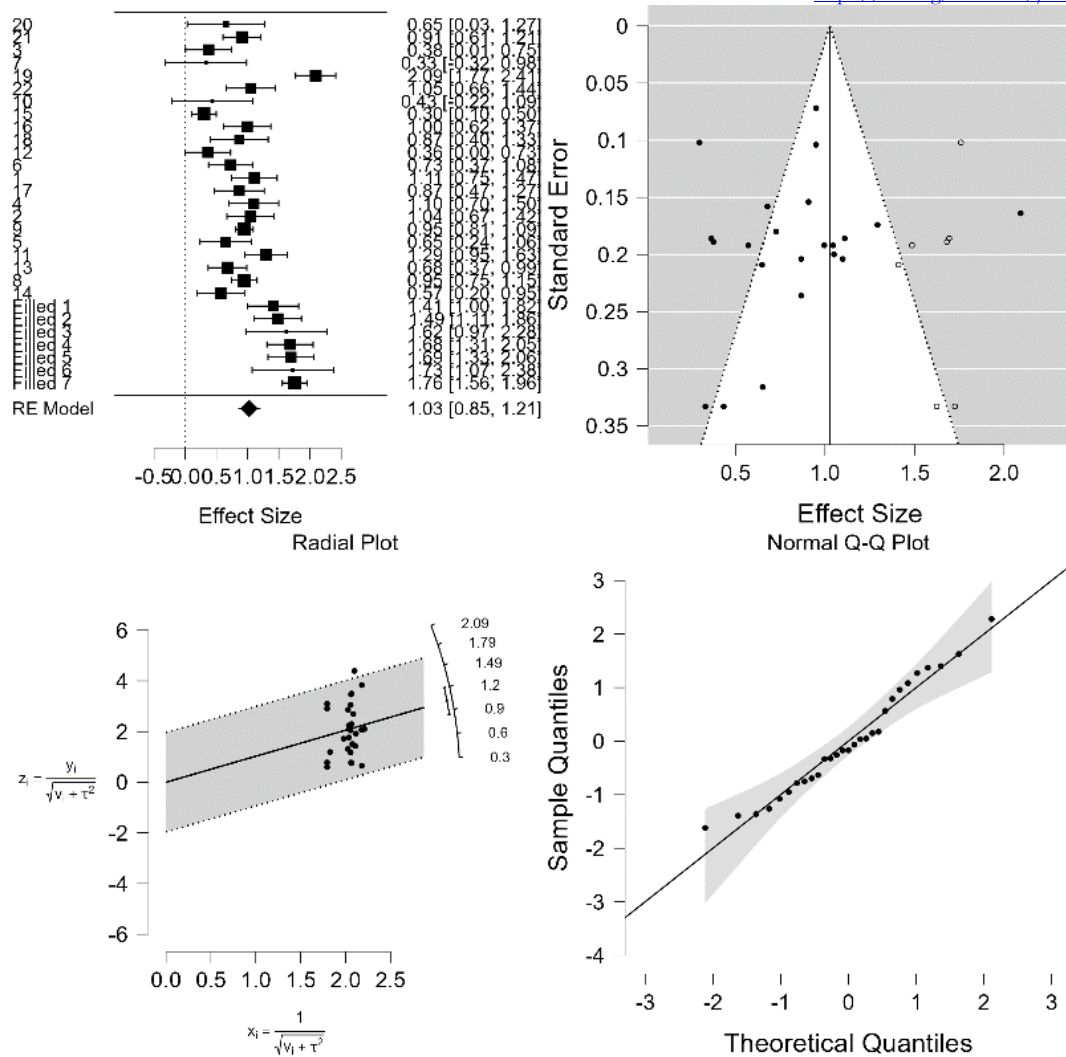


Figure 4. Changes in Forest Plot & Funnel Plot after Trim and Fill, Radial Plot, and Normal Q-Q Plot.

Figure 4 shows that the RE value of the Forest Plot Model after being adjusted by Trim and Fill, shows a more significant increase. This means that the conclusions made based on the fixed-effects model about differences in problem-solving ability in improving student learning outcomes or achievement are valid. Then, there is no open circle in the funnel plot of the fixed-effects model. This means that there is no missing (unpublished) research. Therefore, the conclusion about the difference in problem-solving ability in improving student learning achievement is free from potential publication bias. The radial shows a balance in the point distribution of both significant positive or negative effects appearing on both sides of the axis in the interval (2,-2), indicating that there is no publication bias. The Normal Q-Q Plot shows that the points on the Q-Q plot line up in a straight line, indicating that the distribution of observed effect sizes (after Trim and Fill adjustment) is close to a normal distribution. This is an indication that the estimated effects, after adjustment, do not show significant deviations from normality, which is often considered a prerequisite for some statistical methods in meta-analysis. In conclusion, there is no publication bias from the twenty-two studies on problem-solving ability and student learning outcomes or achievement.

Based on the analysis that has been done from twenty-two studies, it is known that problem-solving skills are very significant in improving student learning outcomes or achievement. The following presents the percentage of research based on grade or school level.

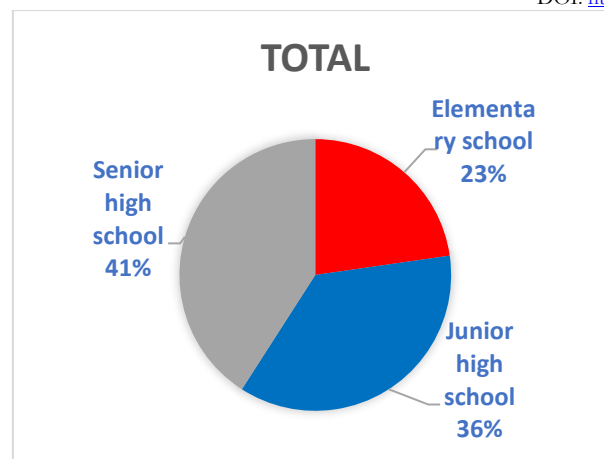


Figure 5. Percentage of research by school level

Figure 5 indicates that senior high school students were the most researched in Indonesia. Problem-solving skills are very appropriate for students at all school levels. It is consistently shown that problem-solving skills significantly impact the academic achievement of elementary, junior high, and senior high school students. The problem-solving skills of students are generally low and suggest that the application of structured inquiry models can help improve these skills. (Cindikia et al., 2020; Pardimin & Widodo, 2016). The Problem-Based Learning (PBL) method in small groups is a proven method to improve problem-solving skills (Klegeris & Hurren, 2011). The results obtained will provide insights for decision-making in the development of education that focuses on improving this skill domain.

Conclusion

A meta-analysis of 22 research articles on problem-solving ability and student learning outcomes found that there was significant heterogeneity among the studies. The high I^2 values indicate that most of the variation among the results is due to substantial differences between studies, not just sampling errors. In addition, significant evidence was found that problem-solving ability positively impacts student learning outcomes, with a strong correlation in the random effects model. This suggests that an increase in students' problem-solving ability correlates with an improvement in their learning outcomes. Analysis using Funnel Plots and statistical methods (rank correlation and regression method) showed that there was no significant evidence of publication bias among the studies analyzed. The larger p-value of both testing methods indicated that the distribution of studies in this meta-analysis was relatively symmetrical, and there was no apparent publication bias. High school students are the most researched in Indonesia with regard to problem-solving skills.

This certainly adds confidence to the findings. However, one should not be hasty in interpreting the results and consider potential sources of heterogeneity when applying the findings to educational practice. Therefore, further analyses are needed to identify and understand sources of heterogeneity, including differences in population characteristics, methodology, or outcome measurement.

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