Al-Ishlah: Jurnal Pendidikan
Vol.17, 3 (September, 2025), pp. 4971-4983
ISSN: 2087-9490 EISSN: 2597-940X, DOI: 10.35445/alishlah.v17i3.7061

Unveiling The Impact of Inquiry-Based Learning: A Meta-Analysis of Student Learning Outcomes

Harleni[1], Ganefri[2], Asmar Yulastri[3], M. Giatman[4], Dedy Irfan[5], Hansi Effendi[6]

[1] Universitas Perintis Indonesia, Padang, Indonesia: harleni.lhenie@gmail.com
[2] Universitas Negeri Padang, Padang, Indonesia; ganefri@unp.ac.id
[3] Universitas Negeri Padang, Padang, Indonesia; yun064@fpp.unp.ac.id
[4] Universitas Negeri Padang, Padang, Indonesia; giatman@ft.unp.ac.id
[5] Universitas Negeri Padang, Padang, Indonesia; dedy_irfan@unp.ac.id
[6] Universitas Negeri Padang, Padang, Indonesia; hans_79@ft.unp.ac.id

ARTICLE INFO

Keywords:

inquiry-based learning;
meta-analysis;
student learning outcomes;
educational effectiveness

Article history:

Received 2025-01-29
Revised 2025-09-22
Accepted 2025-09-29

ABSTRACT

Inquiry-based learning (IBL) has been increasingly adopted in education to foster students' conceptual understanding and critical thinking. However, existing research shows varying results regarding its effectiveness, ranging from significant positive effects to no impact. This study aims to systematically evaluate the impact of IBL on student learning outcomes through a meta-analytic approach. A meta-analysis was conducted on empirical studies published between 2020 and 2024. The study followed the PRISMA protocol, including three stages: identification, screening, and inclusion. A total of 21 relevant studies were selected and analyzed using JASP software to ensure accuracy in calculating effect sizes and interpreting findings. The meta-analysis revealed that inquiry-based learning has a small but significant overall effect on student learning outcomes (effect size: d = 0.444). The impact was particularly evident in science and mathematics education. Additionally, moderating variables such as educational level, instructional design, and student engagement were found to influence the effectiveness of IBL. While the overall effect size is modest, the findings confirm that IBL can positively contribute to student achievement. These results support the continued use and further development of inquiry-based approaches in modern educational contexts. The study provides evidence-based insights for educators, researchers, and policymakers seeking to optimize teaching strategies for 21st-century learning environments.

Corresponding Author:
Harleni
Universitas Perintis Indonesia, Padang, Indonesia: harleni.lhenie@gmail.com

1. INTRODUCTION

Improving the quality of education to enhance student learning outcomes is one of the top priorities in the field of education, both internationally and in Indonesia. This effort aims to develop responsible and knowledgeable human resources capable of facing global challenges (Al Mamun &

Lawrie, 2023; Antonio & Prudente, 2023). Thus, quality education not only produces competent and highly knowledgeable generations but also equips them to navigate an increasingly complex global landscape.

One key indicator of successful learning is student achievement, as good learning outcomes indicate the effectiveness of the educational process in institutions (Asy'ari et al., 2021). To achieve this, various approaches have been implemented to improve student learning outcomes, one of which is the development and application of inquiry-based learning. This learning model emphasizes student exploration, experimentation/investigation, and active engagement in the learning process (Baker et al., 2021).

Inquiry-based learning is grounded in constructivist theory, where students acquire knowledge through direct participation in the learning process. This theory emphasizes that students should not passively receive information but rather engage actively to build their competencies and knowledge independently. Independently acquired competencies tend to be more deeply ingrained in students compared to passive reception or mere listening (Becker et al., 2020; Bhandary et al., 2024). By directly involving students in the learning process—encouraging them to ask questions, seek answers independently, and find solutions on their own—this approach is believed to enhance conceptual understanding, critical thinking, creativity, and problem-solving skills. Inquiry-based learning also fosters self-directed learners with a high sense of curiosity, which is essential for facing the dynamic challenges of the global world (Burhan et al., 2022; Chan et al., 2024).

Inquiry-based learning has been widely implemented in the educational process; however, research findings on its impact vary. This discrepancy necessitates a deeper investigation to comprehensively understand the overall effects of inquiry-based learning on student achievement. Some studies have found that inquiry-based learning significantly enhances students' scientific competencies and technical skills (Juniar, Fardilah, et al., 2021; Nasri et al., 2023; Shofiyah et al., 2020). However, preliminary research suggests that only a few studies report a strong impact on student learning outcomes, while most findings indicate a moderate effect. Additionally, some studies have found that inquiry-based learning has a moderate impact on improving critical thinking skills and scientific competencies (Juniar, Fardilah, et al., 2021; Purba et al., 2021). Conversely, other research suggests that the effect of inquiry-based learning is small in enhancing critical thinking skills, scientific competencies, and student knowledge (Khery et al., 2020; Noer et al., 2020; Sharmila et al., 2022).

Beyond positive impacts—whether large, moderate, or small—some studies have shown that inquiry-based learning has no significant effect on student learning outcomes, particularly in terms of conceptual understanding and critical thinking skills. Previous research has also found that inquiry-based learning does not necessarily enhance students' critical thinking skills (Abidin et al., 2021; Koes-H et al., 2020). Moreover, some studies indicate that this learning approach does not significantly improve student knowledge (conceptual understanding) (Abdellateef Alqawasmi et al., 2024; Ramnarain, 2024; Thongkoo et al., 2024). The diversity of these findings presents a fundamental issue in this study, necessitating a comprehensive analysis to determine the true impact of inquiry-based learning on student achievement.

Understanding the overall impact of inquiry-based learning is crucial for educators and educational institutions to effectively implement this model in the learning process (Sukardi et al., 2024). Therefore, this study adopts a meta-analysis research method to address the identified research problem. Through meta-analysis, this study synthesizes findings from various research studies to provide a more comprehensive understanding (Setyawan et al., 2024). The novelty of this study lies in its holistic examination of the impact of inquiry-based learning, distinguishing it from previous empirical research that focused on specific contexts or populations. This study integrates data from multiple studies conducted in diverse educational settings. Additionally, its findings are expected to bridge gaps in the literature by providing more solid and reliable empirical evidence, thus supporting the development of more effective and evidence-based instructional strategies.

This study aims to explore the impact of inquiry-based learning on student learning outcomes through a meta-analysis approach. By conducting this analysis, educators, researchers, and policymakers are expected to gain deeper insights into selecting effective, relevant, and evidence-based teaching strategies. Consequently, inquiry-based learning can be optimized for implementation in various educational contexts, both locally and globally. Moreover, the results of this meta-analysis are expected to serve as a reference for developing educational policies that promote active and innovative learning, ultimately creating more dynamic and responsive learning environments that meet students' needs in the modern era.

2. METHODS

2.1 Article Collection Technique

In line with the objective of this study—to comprehensively evaluate the effectiveness of e-learning in vocational schools—a meta-analysis approach is employed. Meta-analysis is a systematic and quantitative research method used to review, synthesize, and statistically estimate the findings of previous studies addressing the same research problem. These prior studies serve as the primary data sources for the meta-analysis (Dai & Martins, 2024; Setyawan et al., 2024).

The process of identifying relevant studies follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. PRISMA provides a structured and transparent approach for selecting articles pertinent to the research topic, making it particularly effective for sourcing primary data in meta-analytic research. The PRISMA methodology comprises four sequential phases: identification, screening, eligibility assessment, and final inclusion (Syafii et al., 2022; Wahono et al., 2020).

Article searches are conducted using reputable academic databases, including IOPscience and IEEE. Additionally, articles are sourced directly from internationally recognized journals such as the *International Journal of Interactive Mobile Technologies (iJIM)* and the *International Journal of Information and Education Technology (IJIET)*.

2.2 Inclusion and Exclusion Criteria

The inclusion and exclusion criteria serve as systematic guidelines for selecting articles to be used as primary data sources in the meta-analysis. These criteria are essential for ensuring that the selected studies provide comparable and relevant data and adhere to predefined methodological standards. The inclusion criteria specify the characteristics that articles must possess to be eligible for inclusion in the analysis, whereas the exclusion criteria identify and eliminate studies that do not meet these established requirements.

The inclusion criteria are based on five key aspects: scientific field, year of publication, article type, research design, and the nature of research data (Agussuryani et al., 2022; Syafii et al., 2022). A detailed summary of these criteria is provided in Table 1. Conversely, the exclusion criteria stipulate that any article failing to satisfy one or more of the inclusion parameters outlined in Table 1 will be excluded from the meta-analysis and not considered as a primary data source.

Table 1. Inclusion Criteria for Article Selection

No	Criteria	Inclusion
1	Topic Focus	Articles discussing the impact of inquiry-based learning implementation in educational institutions.
2	Year of Publication	Articles published between 2020 and 2024.
3	Article Type	Articles published in international journals or conference proceedings.
4	Research	Articles employing experimental research methods with a control and experimental

	Design	group to implement e-learning in the learning process.
5	Research Data	Articles containing post-test data from control and experimental groups, including mean (M), sample size (N), and standard deviation (SD).

2.3 Data Analysis Technique

The data analysis technique used in this meta-analysis follows the *random effect model* with Restricted Maximum Likelihood (Restricted ML). To apply this analysis technique, the collected data must first meet the heterogeneity test requirements. The analyzed data includes the effect size (d) and standard error (SEg) obtained from the primary data of the meta-analysis articles.

To compute the values of d and SEg, each meta-analysis article must contain sample size (N), mean (M), and standard deviation (SD) from post-test scores of the students (Lo & Hew, 2019; Wahono et al., 2020). These data points align with the inclusion criteria established for article selection in this meta-analysis. The effect size is calculated using Equation (1), while the standard error is determined using Equation (2) (Goulet-Pelletier & Cousineau, 2020).

$$d = \frac{M_2 - M_1}{\sqrt{\frac{(n_1-1)S_1^2+(n_2-1)S_2^2}{n_1+n_2-2}}} \quad (1)$$

$$SE_g = \sqrt{J \times V_d} \quad (2)$$

$$J = 1 - \frac{3}{4(n_1+n_2-2)-1} \quad (3)$$

$$V_d = \frac{n_1+n_2}{n_1.n_2} + \frac{d^2}{2(n_1+n_2)} \quad (4)$$

The four equations used can be explained as follows: d represents the calculated effect size, M_2 is the mean score of the experimental group, and M_1 is the mean score of the control group. n_1 refers to the sample size of the control group, while n_2 represents the sample size of the experimental group. S_1^2 denotes the variance of the control group, and S_2^2 denotes the variance of the experimental group. SEg is the standard error of the effect size, while J is a correction factor used to reduce bias in the effect size calculation. The final variable, Vd, represents the variance of the effect size, which can be determined using Equation (4) (Arlinwibowo et al., 2022; Goulet-Pelletier & Cousineau, 2020)

3. FINDINGS AND DISCUSSION

Based on the search results for articles related to this study, a total of 205 articles were found that examine the impact of inquiry-based learning in educational institutions. These articles are distributed across various sources: 145 articles from IOPscience, 37 articles from IEEE, 9 articles from IJIM, and 14 articles from IJIET. The first stage of analysis was conducted by broadly examining the main topics of the articles to determine whether they discuss the impact of inquiry-based learning on student learning outcomes. Through this selection process, 83 articles were identified as relevant to this meta-analysis.

A second analysis was then conducted by applying inclusion criteria to assess the articles in greater depth, ensuring that the data and discussions presented were reliable for this meta-analysis. As a result, 25 articles were deemed reliable for further analysis. However, after reviewing the research findings and data provided in the articles, 3 articles were found not to include the impact on student learning outcomes, and 1 article did not use an inquiry-based learning approach. Thus, a total of 21 articles were ultimately included in the study. A more detailed overview of the article screening process is illustrated in Figure 1.

Among the 21 selected articles, 4 articles reported two different impacts of inquiry-based learning on the learning process. First, Purba et al. (2021) stated that inquiry-based learning enhances students' science process skills and critical thinking skills. Second, Thahir et al. (2020) found that STEM-based inquiry learning significantly improves students' scientific attitudes and conceptual understanding. Third, Noer et al. (2020) revealed that inquiry-based learning affects students' reflective thinking skills and self-efficacy. Fourth, Koes-H et al. (2020) reported that integrating inquiry-based learning into the learning process significantly enhances students' prior knowledge and critical thinking skills.

After gathering all the data, an analysis was conducted to determine the effect size and standard error produced in each study. The obtained data and the results of the analysis are presented in Table 2. Based on the overall data collected from 2020 to 2024, studies on this topic were reported in each of these years. The highest number of studies was conducted in 2021, with a total of 10 research studies. The second highest was in 2020, with 9 studies, followed by 1 study in 2022, 2 studies in 2023, and 3 studies in 2024.

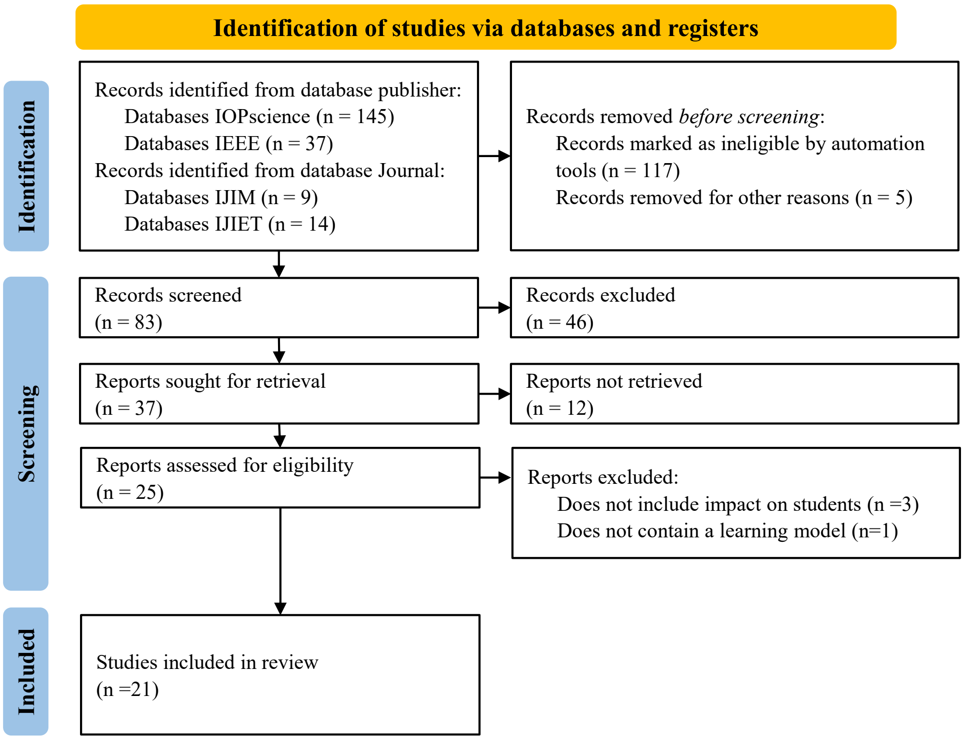

Figure 3. Article Screening Results Using the PRISMA Method

Figure 3 illustrates the article screening process based on the PRISMA method, outlining each phase from identification to final inclusion. Table 2 presents a summary of the selected articles that met all inclusion criteria and were deemed suitable for use in the meta-analysis. These articles represent a comprehensive dataset drawn from various credible sources, ensuring the reliability and validity of the findings. The consistency of the screening process and the diversity of the selected studies contribute to the robustness of the meta-analytic results.

Table 2. Overall Article Data for Meta-Analysis

Writer	Year	Control Class			Experiment Class			*d*	Er
		Nc	Mc	SDc	Ne	Me	SDe		
Juniar et al.,	2021	33	78.40	6.90	33	89.60	7.70	0.75	0.25
Abidin et al.,	2021	24	69.87	9.90	24	57.15	7.00	-0.84	0.30
Khery et al.,	2020	27	66.19	3.10	27	69.80	4.35	0.40	0.27
Purba et al., (Science Process Skills)	2021	31	66.23	4.92	30	73.00	6.91	0.55	0.26
Purba et al., (Critical Thinking Skills)	2021	31	62.71	13.20	30	71.22	9.88	0.43	0.26
Sharmila et al.,	2022	35	63.20	10.37	35	70.85	10.00	0.40	0.24
Thahir et al., (Scientific Attitude)	2020	29	74.00	6.84	29	85.00	10.73	0.78	0.27
Thahir et al., (Conceptual Understanding)	2020	29	65.00	7.13	29	72.00	9.06	0.49	0.26
Noer et al., (Reflective Thinking Skills)	2020	28	19.71	7.79	28	25.50	8.98	0.40	0.27
Noer et al., (Self-Efficacy)	2020	28	86.00	9.08	28	87.54	8.51	0.10	0.27
Wijaya et al.,	2020	30	65.33	8.29	30	74.60	5.84	0.59	0.26
Asy'ari et al.,	2021	22	2.14	0.50	22	3.36	0.53	0.37	0.30
Juniar, Silalahi, et al.,	2021	26	18.08	3.33	56	31.11	2.32	1.41	0.26
Koes-H et al., (Prior Knowledge)	2020	29	45.03	16.73	30	42.35	15.78	-0.12	0.26
Koes-H et al., (Critical Thinking Skills)	2020	29	27.77	11.69	30	29.12	9.56	0.07	0.26
Shofiyah et al.,	2020	34	42.00	6.21	34	63.47	7.74	1.49	0.27
Ramnarain,	2024	166	2.05	0.33	166	3.41	0.45	0.18	0.11
Kharismayuni et al.,	2021	25	81.28	9.22	25	87.20	8,25	0.39	0.28
Pulungan et al.,	2021	32	58.47	8.66	33	66.12	11.70	0.46	0.25
Dwirahayu et al.,	2021	36	60.56	20.03	36	70.69	15.22	0.38	0.24
Nasri et al.,	2023	23	76.52	4.78	22	93.44	4.38	1.63	0.34
Dewi et al.,	2021	38	9.68	1.17	38	11.08	1.92	0.21	0.23
Marion et al.,	2023	30	50.20	18.63	30	65.13	18.00	0.64	0.26
Thongkoo et al.,	2024	176	7.61	2.58	170	9.22	2.87	0.08	0.11
Abdellateef Alqawasmi et al.,	2024	35	16.97	1.76	36	18.19	2.21	0.16	0.24

Note: Control group sample size (Nc), Control group mean (Mc), Control group standard deviation (SDc), Experimental group sample size (Ne), Experimental group mean (Me), Experimental group standard deviation (SDe), Effect size (d), Standard error (Er).

After all the data have been collected, as shown in Table 2, a meta-analysis will be conducted using the JASP software. The overall results of the meta-analysis can be seen in the forest plot effect size shown in Figure 2. Based on the obtained results, it is evident that the impact of inquiry-based learning varies across each study. The lowest effect size is -0.84, which was found in the study by Abidin et al. (2021). Their findings showed that problem-based learning (PBL) was more effective in improving students' mathematical reasoning skills compared to the inquiry learning model. On the other hand, the best result was found by Thahir et al. (2020), with an effect size of 0.78, stating that inquiry-based learning significantly enhances students' scientific attitude. To specifically assess the overall impact of inquiry-based learning, the results are presented in Table 3. From this, it can be concluded that the obtained effect size is 0.444. When interpreted using Cohen's d criteria, the effect size falls under the small category (Goulet-Pelletier & Cousineau, 2020). Therefore, it can be concluded that inquiry-based learning has a small impact on improving students' knowledge in the learning process at educational institutions.

Table 3. Meta-Analysis Effect Size Test Results

Estimate	Standard Error	z	p	95% Confidence Interval
				Lower
intercept	0.444	0.102	4.347	< 0.001

Additionally, the standard error value of 0.102 indicates that the level of uncertainty in the effect size estimate is very low, meaning the results obtained can be considered quite stable and accurate. The z-value of 4.347 suggests a strong relationship between the analyzed variables, and the result is highly statistically significant, as reinforced by the p-value of < 0.001, which means the probability of this result occurring by chance is very small, almost close to zero. Furthermore, the 95% confidence interval ranging from 0.244 to 0.644 provides evidence that the true effect size is almost certainly within this interval. Since this range does not include zero, it can be concluded that the found effect is not only statistically significant but also practically meaningful. Overall, this analysis provides a high level of confidence in the validity and reliability of the results, showing a real and consistent effect, supporting the existence of a significant relationship between inquiry-based learning and students' learning outcomes in educational institutions.

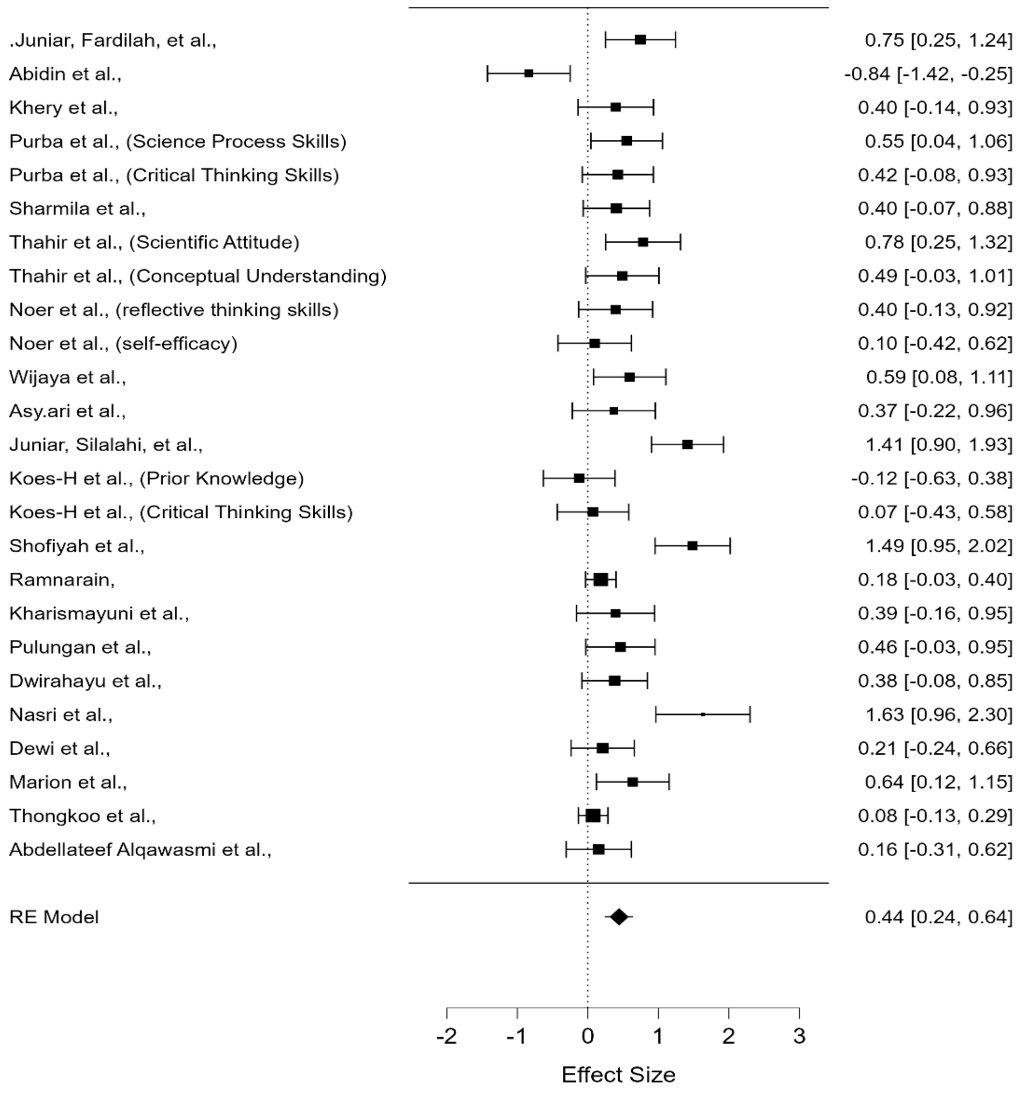

Figure 2. Forest Plot Effect Size Results

After obtaining the results from the meta-analysis, it is essential to examine the potential bias in the research articles used. This step aims to enhance the validity of the data and the results of the meta-analysis conducted (Dai & Martins, 2024; Setyawan et al., 2024). The first test is performed by examining the funnel plot produced by all the studies included in this meta-analysis, as shown in Figure 3. The funnel plot is used to assess the potential publication bias in the meta-analysis. The points representing the studies are spread around the central vertical line, which indicates the average effect size, with a relatively symmetrical distribution. Studies with small standard errors (large sample sizes) are concentrated near the top of the funnel, while studies with larger standard errors (small sample sizes) are spread more widely at the bottom. The symmetry of the plot indicates that the potential for publication bias is low, as there are no significant deviations or patterns showing that certain study results tend to be unreported. However, to confirm this conclusion, additional analyses such as Kendall's τ test, Egger's test, and fail-safe N are conducted. The results obtained from these tests are presented in Table 4.

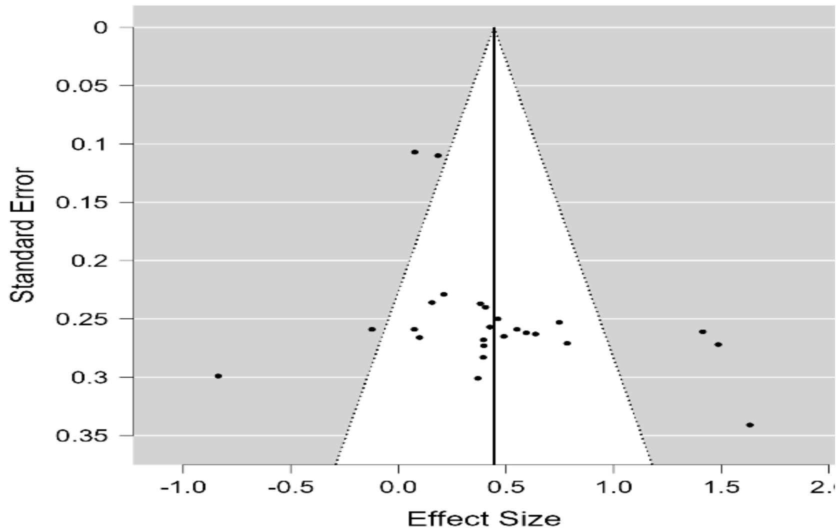

Figure 3. Publication Bias Testing Results from Funnel Plot

The analysis of publication bias in this meta-analysis shows that Kendall's τ has a value of 0.238 with a p-value of 0.097. Based on these results, it can be concluded that there is no statistically significant indication of publication bias ($p > 0.05$). Kendall's τ test is used to evaluate the relationship between effect size and sample size in individual studies, where a non-significant p-value indicates that the distribution of study effects is not affected by publication bias. Next, Egger's Test produces a z value of 1.405 with a p-value of 0.160, also showing no significant asymmetry in the funnel plot ($p > 0.05$). Egger's Test is used to detect the presence of publication bias through regression analysis on the funnel plot, and this result indicates that the meta-analysis is free from asymmetry bias. Overall, both tests consistently show that publication bias does not significantly affect the reliability of this meta-analysis. Furthermore, the Fail-safe N value is 687,000 with a p-value of 0.001. The Fail-safe N obtained will be compared with the equation 5K + 10 (135); comparing these values, it is found that the Fail-safe N value (687,000) is much larger than 5K + 10 (135). This large value of Fail-safe N indicates that the meta-analysis results are very stable and not susceptible to publication bias. Overall, these findings show that this meta-analysis is free from significant publication bias and has a high level of reliability.

Table 4. Results of Bias Testing with Kendall's τ, Egger's Test, and Fail-safe N

Analysis	Calculated Value	p-value
Kendall's τ	0.238	0.097
Egger's Test (z)	1.405	0.160
Fail-safe N	687.000	0.001

Discussion

Based on the results of the meta-analysis, it is evident that the impact of inquiry-based learning varies. The lowest effect size is (d = -0.84), while the highest is (d = 1.63). However, the overall average effect size obtained is (d = 0.444) with a p-value of (0.001). These results indicate that inquiry-based learning has a moderate impact on the learning process. Although the impact is moderate, it is significant enough to improve student learning outcomes. The variation in the results is attributed to differences in the context of implementing inquiry-based learning and the quality of teachers in the learning process (Hinostroza et al., 2024; Strat et al., 2024). For example, (Abidin et al., 2021) applied seven steps of inquiry-based learning: asking questions, formulating hypotheses, designing experiments, conducting experiments, analyzing data, drawing conclusions, and applying the results, which yielded less favorable results. Meanwhile, (Nasri et al., 2023) applied six steps of inquiry-based learning: Orientation, Conceptualization, Conducting Investigations, Analyzing Data, Conclusion, and Reflection, which resulted in excellent outcomes.

In the learning process, researchers also integrated STEM (Science, Technology, Engineering, and Mathematics) with inquiry-based learning. The learning process involved eight steps: asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, engaging in arguments from evidence, and obtaining, evaluating, and communicating information. This study found a moderate impact on improving student character and a small impact on enhancing knowledge (conceptual understanding) (Thahir et al., 2020). Meanwhile, (Marion et al., 2023) integrated digital technology (GeoGebra) into inquiry-based learning, which used seven learning steps: orientation, asking questions, experiments, collecting and analyzing data, discussion, conclusion, and evaluation. The results showed a significant improvement in knowledge (conceptual understanding), with a moderate effect size.

This study also reveals that integrating digital technology into the learning process today is very effective for enhancing student knowledge. The integration of technology in inquiry-based learning plays a crucial role in improving its effectiveness, particularly in supporting exploration and student engagement (Kharismayuni et al., 2021; Pulungan et al., 2021). Technologies such as digital simulations, interactive software, and virtual laboratories can help students understand complex concepts through visualization and virtual experiments. According to constructivist theory, technology use can enhance the learning process by providing a resource-rich learning environment, allowing students to explore knowledge independently (Antonio & Prudente, 2023; Heindl, 2019). Moreover, technology allows students to conduct virtual experiments that may not be possible in the classroom due to time, cost, or risk constraints. By utilizing technology, inquiry-based learning can reach more students, increasing active participation and supporting the development of 21st-century skills such as critical thinking, collaboration, and digital literacy (Hinostroza et al., 2024; Muhamad Dah et al., 2024). This integration also helps teachers monitor student progress in real-time, offering opportunities to provide more targeted guidance. Thus, technology is not just a tool but a catalyst for enhancing the effectiveness of inquiry-based learning (Becker et al., 2020; Chan et al., 2024).

Additionally, the teacher's skills in implementing inquiry-based learning are a key determinant of the success of this approach. Based on constructivist theory, teachers act as facilitators guiding students to build their knowledge through exploration, experimentation, and problem-solving.

However, teachers who lack a deep understanding of inquiry methods may struggle to create a learning environment that enables active student engagement (Jegstad, 2024; Muhamad Dah et al., 2024). Furthermore, Vygotsky (1978) emphasized the importance of teachers providing appropriate scaffolding so that students can surpass their current abilities through the zone of proximal development (ZPD). Teachers who fail to provide sufficient guidance can leave students feeling lost in the inquiry process, preventing learning goals from being achieved (Antonio & Prudente, 2023; Syahwin et al., 2022). Therefore, intensive training for teachers to understand inquiry strategies, including how to ask thought-provoking questions and guide student exploration, is essential. Moreover, the success of inquiry-based learning also depends on the teacher's ability to integrate supportive technologies, such as digital simulations or interactive software, to facilitate more effective student exploration (Allen et al., 2022; Nguyen et al., 2022).

The implications of this study suggest that inquiry-based learning has great potential to improve student learning outcomes, particularly in the areas of critical thinking skills, scientific process skills, and curiosity, although its overall impact is modest. This calls for educators and policymakers to prioritize teacher training in inquiry strategies and integrate relevant technologies to support learning (Herut & Setlhako, 2025; Kärkkäinen et al., 2023). Additionally, schools and educational institutions must ensure that inquiry-based learning is designed with consideration of the student context, available resources, and adequate teacher guidance. Further research is needed to explore how inquiry-based learning can be adapted to various conditions and combined with other approaches, such as technology-based learning, to maximize its impact. With these steps, inquiry-based learning is expected to become a more effective and relevant approach in supporting student development in the 21st-century educational era.

4. CONCLUSION

Based on the findings of this study, which reviewed 21 articles on the implementation of inquiry-based learning, it can be concluded that this approach has a small but statistically significant effect on improving student learning outcomes, with an effect size of $d = 0.444$ and a p-value of 0.001. Despite the relatively small effect size, the statistical significance indicates that inquiry-based learning contributes meaningfully to educational outcomes. Moreover, the validity of these results is supported by the absence of publication bias, as confirmed through funnel plot analysis, Kendall's τ test, Egger's test, and the Fail-safe N test. However, a limitation of this meta-analysis lies in the relatively small number of studies included, which may affect the generalizability of the findings across different contexts, subjects, or educational levels. Future research is encouraged to expand the dataset by incorporating a broader range of studies, exploring the differential effects of inquiry-based learning across various disciplines, and examining moderating variables such as student demographics, instructional design, and implementation fidelity to deepen the understanding of its effectiveness in diverse educational settings.

REFERENCES

Abdellateef Alqawasmi, Najeh Rajeh Alsalhi, & Sami Sulieman Al Qatawneh. (2024). The Influence of Utilizing Inquiry-Based Learning Strategy on Science Accomplishment of Primary Students' Stage. *International Journal of Interactive Mobile Technologies (IJIM)*, *18*(05), 62–76. https://doi.org/10.3991/ijim.v18i05.47011

Abidin, Z., Sutama, Herman, T., Jupri, A., Farokhah, L., Apuanor, & Sonedi. (2021). Gifted Children's Mathematical Reasoning Abilities on Problem-Based Learning and Project-Based Learning Literacy. *Journal of Physics: Conference Series*, *1720*(1), 012018. https://doi.org/10.1088/1742-6596/1720/1/012018

Agussuryani, Q., Sudarmin, S., Sumarni, W., Cahyono, E., & Ellianawati, E. (2022). STEM literacy in growing vocational school student HOTS in science learning: A meta-analysis. *International Journal of Evaluation and Research in Education (IJERE)*, *11*(1), 51. https://doi.org/10.11591/ijere.v11i1.21647

Al Mamun, M. A., & Lawrie, G. (2023). Student-content interactions: Exploring behavioural engagement with self-regulated inquiry-based online learning modules. *Smart Learning Environments*, *10*(1), 1. https://doi.org/10.1186/s40561-022-00221-x

Allen, T., O'Loughlin, M., & Croker, F. (2022). Teaching health promotion competencies in undergraduate dentistry training: A unique pedagogical approach. *Health Promotion Journal of Australia*, *33*(S1), 35–38. https://doi.org/10.1002/hpja.660

Antonio, R. P., & Prudente, M. S. (2023). Effects of Inquiry-Based Approaches on Students' Higher-Order Thinking Skills in Science: A Meta-Analysis. *International Journal of Education in Mathematics, Science and Technology*, *12*(1), 251–281. https://doi.org/10.46328/ijemst.3216

Arlinwibowo, J., Retnawati, H., & Kartowagiran, B. (2022). The impact of ICT utilization to improve the learning outcome: A meta-analysis. *International Journal of Evaluation and Research in Education (IJERE)*, *11*(2), 522. https://doi.org/10.11591/ijere.v11i2.22112

Asy'ari, M., Prayogi, S., Mirawati, B., Syarifuddin, Hunaepi, Syahrir, & Suhirman. (2021). Development of physics learning tools based on inquiry to increase creative thinking skills. *Journal of Physics: Conference Series*, *1816*(1), 012094. https://doi.org/10.1088/1742-6596/1816/1/012094

Baker, R. S., Gašević, D., & Karumbaiah, S. (2021). Four paradigms in learning analytics: Why paradigm convergence matters. *Computers and Education: Artificial Intelligence*, *2*(March), 100021. https://doi.org/10.1016/j.caeai.2021.100021

Becker, S., Klein, P., Gößling, A., & Kuhn, J. (2020). Using mobile devices to enhance inquiry-based learning processes. *Learning and Instruction*, *69*(April), 101350. https://doi.org/10.1016/j.learninstruc.2020.101350

Bhandary, M., Thimmaiah, C., Shahid, M., Shetty, Y., & Rao K, A. (2024). Potential of active learning in dentistry: A comparative study of Jigsaw versus inquired-based learning. *Journal of Dental Education*, *88*(11), 1442–1449. https://doi.org/10.1002/jdd.13678

Burhan, A., Khusein, N. bin A., & Sebayang, S. M. (2022). Effectiveness of negative pressure wound therapy on chronic wound healing: A systematic review and meta-analysis. *Belitung Nursing Journal*, *8*(6), 470–480. https://doi.org/10.33546/BNJ.2220

Chan, S. L., Fung, J. T. C., Takemura, N., Chau, P. H., Lee, J. J. J., Choi, H. R., Wan, W. H., Withrow, H., & Lin, C. (2024). Enhancing nursing students' cultural awareness through Community of Inquiry-guided online 'Internationalization at Home' strategies—An intervention study. *Nursing Open*, *11*(8), 1–11. https://doi.org/10.1002/nop2.2251

Dai, L., & Martins, P. S. (2024). Does vocational education pay off in China? Evidence from city-level education supply shocks. *Economic Modelling*, *140*(4), 106863. https://doi.org/10.1016/j.econmod.2024.106863

Dewi, D. K., Ardhana, W., Irtadji, Chusniyah, T., & Sulianti, A. (2021). Inquiry-Based Learning Implementation to Improve Critical Thinking of Prospective Teachers. *International Journal of Information and Education Technology*, *11*(12), 638–645. https://doi.org/10.18178/ijiet.2021.11.12.1575

Dwirahayu, G., Mas'ud, A., Satriawati, G., Atiqoh, K. S. N., & Dewi, S. (2021). Improving students' mathematical creative reasoning on polyhedron through concept-based inquiry model. *Journal of Physics: Conference Series*, *1836*(1), 012073. https://doi.org/10.1088/1742-6596/1836/1/012073

Goulet-Pelletier, J.-C., & Cousineau, D. (2020). A review of effect sizes and their confidence intervals, Part I: The Cohen's d family. *The Quantitative Methods for Psychology*, *16*(4), 422–423. https://doi.org/10.20982/tqmp.16.4.p422

Heindl, M. (2019). Inquiry-based learning and the pre-requisite for its use in science at school: A meta-analysis. *Journal of Pedagogical Research*, *3*(2), 52–61. https://doi.org/10.33902/JPR.2019254160

Herut, A. H., & Setlhako, M. A. (2025). Shaping future preschool teachers in Ethiopia: A qualitative evaluation of pedagogical competence development mechanisms. *Social Sciences and Humanities Open*, *11*(September 2024), 101218. https://doi.org/10.1016/j.ssaho.2024.101218

Hinostroza, J. E., Armstrong-Gallegos, S., & Villafaena, M. (2024). Roles of digital technologies in the implementation of inquiry-based learning (IBL): A systematic literature review. *Social Sciences and Humanities Open*, *9*(November 2023), 100874. https://doi.org/10.1016/j.ssaho.2024.100874

Jegstad, K. M. (2024). Inquiry-based chemistry education: a systematic review. *Studies in Science Education*, *60*(2), 251–313. https://doi.org/10.1080/03057267.2023.2248436

Juniar, A., Fardilah, R. D., & Tambunan, P. M. (2021). The Distinction of Students' Science Process Skill and Learning Activities between Guided Inquiry and Conventional Learning with Experiment. *Journal of Physics: Conference Series*, *1788*(1), 012043. https://doi.org/10.1088/1742-6596/1788/1/012043

Juniar, A., Silalahi, A., & Suyanti, R. D. (2021). The Effect of Guided Inquiry-based Learning with Creative Thingking Ability towards Students' Scientific Process Skill in Analytical Chemistry Courses. *Journal of Physics: Conference Series*, *1819*(1), 012009. https://doi.org/10.1088/1742-6596/1819/1/012009

Kärkkäinen, K., Jääskelä, P., & Tynjälä, P. (2023). How does university teachers' pedagogical training meet topical challenges raised by educational research? A case study from Finland. *Teaching and Teacher Education*, *128*. https://doi.org/10.1016/j.tate.2023.104088

Kharismayuni, E., Feronika, T., & Yunita, L. (2021). Implication of thinking maps assisted inquiry model for higher order thinking skills (HOTS) on chemistry. *Journal of Physics: Conference Series*, *1836*(1), 012078. https://doi.org/10.1088/1742-6596/1836/1/012078

Khery, Y., Nufida, B. A., Suryati, S., Rahayu, S., & Aini, M. (2020). The Influence of Mobile-NOS Model of Learning towards Students Understanding on the Nature of Science. *Journal of Physics: Conference Series*, *1464*(1[1] Y. Khery, B. A. Nufida, S. Suryati, S. Rahayu, and M. Aini, "The Influence of Mobile-NOS Model of Learning towards Students Understanding on the Nature of Science," J. Phys. Conf. Ser., vol. 1464, issue 1, pp. 012015, Feb. 2020, doi: 10.1088/1742-6596/1), 012015. https://doi.org/10.1088/1742-6596/1464/1/012015

Koes-H, S., Pradana, S. D. S., & Suwasono, P. (2020). Integration conceptual scaffolding in the group investigation: its influence on students' critical thinking skills. *Journal of Physics: Conference Series*, *1481*(1), 012132. https://doi.org/10.1088/1742-6596/1481/1/012132

Lo, C. K., & Hew, K. F. (2019). The impact of flipped classrooms on student achievement in engineering education: A meta-analysis of 10 years of research. *Journal of Engineering Education*, *108*(4), 523–546. https://doi.org/10.1002/jee.20293

Marion, Z., Abdullah, A. H., & Rahman, S. N. S. A. (2023). The Effectiveness of the GeoGebra-Assisted Inquiry-Discovery Learning Strategy on Students' Mastery and Interest in Algebraic Expressions. *International Journal of Information and Education Technology*, *13*(11), 1681–1695. https://doi.org/10.18178/ijiet.2023.13.11.1977

Muhamad Dah, N., Mat Noor, M. S. A., Kamarudin, M. Z., & Syed Abdul Azziz, S. S. (2024). The impacts of open inquiry on students' learning in science: A systematic literature review. *Educational Research Review*, *43*(February), 100601. https://doi.org/10.1016/j.edurev.2024.100601

Nasri, N. M., Nasri, N., Nasri, N. F., & Talib, M. A. A. (2023). The Impact of Integrating an Intelligent Personal Assistant (IPA) on Secondary School Physics Students' Scientific Inquiry Skills. *IEEE Transactions on Learning Technologies*, *16*(2), 232–242. https://doi.org/10.1109/TLT.2023.3241058

Nguyen, M. X. N. C., Dao, P., & Iwashita, N. (2022). Nurturing Teachers' Research Mindset in an Inquiry-Based Language Teacher Education Course. *Modern Language Journal*, *106*(3), 599–616. https://doi.org/10.1111/modl.12795

Noer, S. H., Gunowibowo, P., & Triana, M. (2020). Improving students' reflective thinking skills and self-efficacy through scientific learning. *Journal of Physics: Conference Series*, *1581*(1), 012036. https://doi.org/10.1088/1742-6596/1581/1/012036

Pulungan, M. S., Nasution, D., & Rahmatsyah. (2021). The effect of scientific inquiry learning model and scientific attitude on students' science process skills. *Journal of Physics: Conference Series*, *1811*(1), 012003. https://doi.org/10.1088/1742-6596/1811/1/012003

Purba, E. R., Siregar, N., & Sinulingga, K. (2021). The Experiment of Heat Matter Based on Scientific Inquiry in Senior High School. *Journal of Physics: Conference Series*, *1811*(1), 012132. https://doi.org/10.1088/1742-6596/1811/1/012132

Ramnarain, U. (2024). Pedagogical beliefs of South African physics teachers for inquiry approaches. *Journal of Physics: Conference Series*, *2727*(1), 012029. https://doi.org/10.1088/1742-6596/2727/1/012029

Setyawan, H., Sukardi, Risfendra, Jalinus, N., Mardizal, J., & Ananda, G. F. (2024). Effectiveness of E-Learning-Based Learning in the Era of Digital Transformation: A Meta-Analysis. *Indonesian Journal of Educational Research and Review*, *7*(2), 333–346. https://doi.org/10.23887/ijerr.v7i2.76166

Sharmila, Putra, A., Islami, N., & Putra, A. D. (2022). Integration of Laboratory Activities and Contribution to Result of Learning Physics on The Concept of Fluid in High School Physics Learning. *Journal of Physics: Conference Series*, *2309*(1), 012080. https://doi.org/10.1088/1742-6596/2309/1/012080

Shofiyah, N., Afrilia, I., & Wulandari, F. E. (2020). Scientific Approach and The Effect on Students Scientific Literacy. *Journal of Physics: Conference Series*, *1594*(1), 012015. https://doi.org/10.1088/1742-6596/1594/1/012015

Strat, T. T. S., Henriksen, E. K., & Jegstad, K. M. (2024). Inquiry-based science education in science teacher education: a systematic review. *Studies in Science Education*, *60*(2), 191–249. https://doi.org/10.1080/03057267.2023.2207148

Sukardi, Setyawan, H., Risfendra, Usmeldi, & Yanto, D. T. P. (2024). Effectiveness of Robotic Technology in Vocational Education: A Meta-Analysis. *International Journal of Information and Education Technology*, *14*(4), 521–532. https://doi.org/10.18178/ijiet.2024.14.4.2073

Syafii, A., Machali, I., Putro, N. H. P. S., Retnawati, H., & 'aziz, H. (2022). The effects of multiple intelligences theory on learning success: A meta-analysis in social science. *International Journal of Evaluation and Research in Education*, *11*(2), 736–743. https://doi.org/10.11591/ijere.v11i2.22223

Syahwin, Hardianti, T., & Fitriana, S. (2022). The Effect of Guided Inquiry Learning by Virtual Laboratory Assistance in Physics Learning in Indonesian Senior High Schools: A Meta-Analysis. *International Journal of Instruction*, *15*(4), 101–114. https://doi.org/10.29333/iji.2022.1546a

Thahir, A., Anwar, C., Saregar, A., Choiriah, L., Susanti, F., & Pricilia, A. (2020). The Effectiveness of STEM Learning: Scientific Attitudes and Students' Conceptual Understanding. *Journal of Physics: Conference Series*, *1467*(1), 012008. https://doi.org/10.1088/1742-6596/1467/1/012008

Thongkoo, K., Daungcharone, K., & Panjaburee, P. (2024). Effects of Collaborative Inquiry-Based Online Approach in Thai University Students' Computing Program. *International Journal of Information and Education Technology*, *14*(2), 302–309. https://doi.org/10.18178/ijiet.2024.14.2.2052

Wahono, B., Lin, P. L., & Chang, C. Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. *International Journal of STEM Education*, *7*(1), 1–18. https://doi.org/10.1186/s40594-020-00236-1

Wijaya, A. M. Y., Hobri, Prastiti, T. D., Dafik, & Suratno. (2020). The analysis of learning materials implementation using inquiry based learning method to enhance student's critical thinking skills in solving two dimensional problem. *Journal of Physics: Conference Series*, *1465*(1), 012065. https://doi.org/10.1088/1742-6596/1465/1/012065