Effect of Inquiry-based Learning on Students' Critical Thinking: A Meta-analysis

ABSTRACT

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Recognizing that previous studies have yielded mixed results, this meta-analysis seeks to assess the overall impact of inquiry-based learning (IBL) models on learners' critical thinking skills while also examining the consistency of these outcomes through sensitivity analysis and evaluation of publication bias. A total of 23 effect measures were analyzed from 23 empirical studies published between 2016 and 2025, involving approximately 2,500 participants from various educational backgrounds. The results of the study show that the application of inquiry-based learning has a strong and meaningful influence on students' critical thinking skills. In general, the findings of the study showed consistent differences between the studies analyzed, but the results remained stable despite retesting of the extreme data. Despite indications of publication bias, the influence of inquiry-based learning was still significant after adjustments, thus reinforcing the conclusion that this approach is effective in improving students' critical thinking skills. These findings suggest that IBL is effective in improving critical thinking skills by activating key cognitive processes, such as analysis, inference, and evaluation, and is worthy of wider adoption in 21st-century learning curricula.

Keywords: Inquiry-Based Learning; Critical Thinking; Meta-analysis.

1. Introduction

21st-century education requires students to have critical thinking skills as a provision to face the challenges of a complex and dynamic era. According to Antonio and Prudente (2023), critical thinking is the main requirement for students to solve problems independently, make logical decisions, and objectively assess information in various life situations. The need for these skills has increased significantly because the world of education is currently facing the reality of VUCA (Volatility, Uncertainty, Complexity, dan Ambiguity) which is characterized by an unstable, uncertain, complex, and ambiguous condition (Ey et al., 2021; Seevaratnam et al., 2023; Velazquez, 2024). This situation highlights the importance of critical thinking skills as a vital instrument for survival and rational adaptation in an era of uncertainty.

Critical thinking represents a logical and reflective process of reasoning that determines what is worthy of belief or action. Karakuş (2024) and Quinn et al. (2020) categorize critical thinking skills into two main dimensions: the cognitive dimension and the dispositional dimension. The Cognitive dimension encompasses the ability to analyze, evaluate, and make inferences, while the dispositional dimension is characterized by open-minded, systematic thinking and a confident attitude in decision-making. Finn (2011) and Liu and Pásztor (2022) emphasize that critical thinking skills are the foundation of scientific literacy that is indispensable in evidence- and data-driven decision-making. This skill is a crucial foundation for students to understand problems and respond appropriately and thoroughly.

Research on learning conditions in schools indicates that students' critical thinking skills have not developed optimally. Suryono et al. (2023) and Suyitno et al. (2024) found that the use of conventional learning models and the dominance of expository methods are the main inhibiting factors in the development of critical thinking skills in the school environment. Sharma et al (2023) revealed that the limitation of active interaction in the learning process and the lack of investigation-based learning strategies have a direct impact on the low quality of students' critical thinking, especially at the higher education level. These findings confirm that challenges in the development of critical thinking stem not only from students but also from pedagogical practices that have not undergone substantial transformation (Okolie et al., 2021; Simonovic et al., 2023).

The Inquiry-Based Learning (IBL) approach makes a significant contribution to the development of students' critical thinking skills. Abaniel (2021) and Antonio and Prudente (2023) state that the IBL approach encourages learners to be actively involved in formulating questions, exploring phenomena, analyzing evidence, and drawing conclusions independently. This process allows learners to form a deeper conceptual understanding through reflective and dialogical thinking activities. Explained that the application of IBL creates space to develop logical reasoning and evaluative skills, so that students not only understand information on the surface but also can weigh arguments and evidence critically (Liu & Pásztor, 2022; Martino et al., 2025; Rafiq et al., 2023). Alarcón et al. (2023) and Sharma et al. (2023) confirm that IBL contributes to the improvement of the ability to evaluate arguments and construct scientific knowledge.

Findings from various studies indicate that the application of IBL has a positive impact on enhancing the quality of students' critical thinking. Sharma et al (2023) emphasize that the IBL approach strengthens students' ability to think systematically and draw rational conclusions, especially in the context of inquiry-based learning. Suryono et al. (2023) stated that IBL encourages students to be more active in the learning process, thereby creating intensive

cognitive interaction between students and the problem being studied. Thus, IBL can be considered a relevant pedagogical approach to strengthen critical thinking skills in a learning environment that demands active participation and a deep understanding of knowledge. The demands of students who have engaged in IBL learning should align with theoretical policies and practical applications in education, ensuring they are consistent with student-centered learning as outlined in the national education policy, which emphasizes adaptability, contextuality, and a focus on the optimal development of students' potential. In addition, Sharma et al (2023) research and Suryono et al. (2023) adopted a meta-analysis approach. In the results, it is shown that the study explains the effectiveness of a literature study using a meta-analysis approach.

Meta-analysis is a relevant approach for comprehensively synthesizing the results of diverse research studies. Antonio and Prudente (2023) state that meta-analyses can collect and analyze effect measures from various primary studies to obtain a stronger, more objective, and generalizable overview. Liu and Pásztor (2022) emphasize that this approach allows researchers to assess the effectiveness of IBL in aggregate while evaluating factors that moderate its influence on students' critical thinking skills.

The synthesis of research results is needed to provide a comprehensive picture of the effectiveness of inquiry-based learning on students' critical thinking skills. States that meta-analyses can collect and analyze effect measures from various primary studies in a systematic manner. Liu and Pásztor (2022) affirm that meta-analytic approaches yield stronger, more objective, and generalizable estimates across different educational contexts.

This research is motivated by the need for measurable evidence on the effectiveness of inquiry-based learning in improving students' critical thinking skills. Several previous studies have shown positive results; however, there is no comprehensive synthesis that presents a thorough estimate of the effects and can serve as a basis for evidence-based education policies. The novelty of this study lies in a meta-analysis that comprehensively collects and evaluates the effect measure, accompanied by sensitivity tests and the detection of publication bias to ensure the stability and validity of the findings. This study aims to synthesize the effectiveness of inquiry-based learning on students' critical thinking skills in aggregate using a meta-analysis approach. These objectives include the overall estimation of effect sizes, testing the stability of the results through the analysis of sensitivity to extreme studies, and identifying possible publication bias in the analyzed studies. This study also ensures that the effect size produced is robust and not distorted by asymmetrical data distribution.

The research questions formulated in this study focus on two main aspects.
- The first research question: How does inquiry-based learning affect students' critical thinking skills based on the results of an effect measure meta-analysis?
- The second research question: How do the results of inquiry-based learning meta-analysis affect students' critical thinking skills through funnel plot procedures, Egger's test, trim and fill, and sensitivity analysis?

First, the extent to which inquiry-based learning influences students' critical thinking skills is determined by the results of the meta-analysis of the effect measure. Second, the stability and robustness of the meta-analysis results are evaluated, including an assessment of potential outliers and indications of publication bias, which are examined through funnel plot procedures, Egger's test, trim and fill, and sensitivity analysis.

2. Literature

Definition of inquiry-based learning (IBL)

The development of students' critical thinking skills requires a learning model that encourages the process of investigation, exploration, and reasoning. Duran and Dökme (2016) stated that Inquiry-Based Learning (IBL) is a practical approach in improving students' critical thinking skills in science subjects. The IBL approach emphasizes scientific inquiry activities that require students to ask questions, analyze data, and draw conclusions based on systematic observations and evidence. The research shows that inquiry-based learning activities have a positive impact on improving students' analysis, evaluation, inference, interpretation, explanation, and self-organization skills.

Characteristics of IBL

IBL offers students the opportunity to engage in an active and reflective learning process. Hwang and Chen (2016) stated that the integration of IBL in digital game-based learning design can improve students' motivation, problem-solving, and critical thinking tendencies. Their study confirms that the use of technology and contextual scenarios encourages students to engage in field observation, information search, and reflection on real phenomena. These findings suggest that the effectiveness of IBL increases when associated with an authentic learning environment that brings students closer to real-life situations.

Other research shows that combining the IBL approach with the local cultural context can strengthen critical thinking achievements. Verawati et al. (2022) developed an inquiry-creative learning model that integrates ethnoscience to enhance the critical thinking skills of prospective science teachers. The research indicates that incorporating ethnoscience into learning creates a more meaningful learning experience, as it connects scientific knowledge with students' cultural values and the context of their lives. The measurement results showed significant improvements in all critical thinking indicators, including analysis, inference, evaluation, and decision-making.

The IBL model has different characteristics from traditional learning. Duran and Dökme (2016) compared the two approaches and found that inquiry-based learning is superior in encouraging student active participation, developing cognitive structures, and improving learning outcomes. Inquiry learning positions students as problem solvers, whereas traditional learning positions them as passive recipients of information. This difference has a direct impact on the effectiveness of learning in developing higher-level thinking skills.

Relevant research supporting the IBL model

Several studies have identified variations in the implementation of the IBL model, including guided inquiry and free inquiry. Colburn (2000) states that in guided inquiry, the teacher provides initial direction in the process of formulating questions, while students design their procedures and draw conclusions based on data. This model strikes a balance between student autonomy and the instructional guidance necessary for the development of critical thinking. Duran and Dökme (2016) applied the guided inquiry approach and proved its effectiveness in improving student performance on the overall critical thinking indicator.

Research on the integration of IBL approaches with technology-based or culture-based learning elements remains limited and warrants further exploration. Verawati et al. (2022) emphasized that learning practices that are not holistic and ignore local wisdom often hinder the growth of students' critical reasoning. Therefore, the development of an IBL model that is adaptive to the social and cultural context of students is an essential aspect of learning innovation that encourages optimal critical thinking skills.

3. Methods

Research Approach

This study uses a meta-analysis approach as a quantitative synthesis strategy to evaluate the effectiveness of the Inquiry-Based Learning (IBL) learning model on students' critical thinking skills. This approach is used to obtain a comprehensive, accurate, and generalizable estimate of effect size based on various primary studies published between 2016 and 2025, with the selection of articles presented according to the PRISMA ALIR guidelines. PRISMA ALIR is a guide tool or framework used to conduct research on systematic reviews and meta-analysis. PRISMA ALIR stands for Preferential Reporting Items for Systematic Reviews and MetaAnalyses. Flowcharts, which map the number of records identified, included, and excluded, as well as the reasons why they were excluded, are used to illustrate the flow of information through the different phases of the systematic review (Page et al., 2021). The meta-analysis was chosen because it allows the collection and review of dispersed empirical results, as well as allows researchers to conduct systematic moderator analysis and test publication bias as seen in Figure 1.
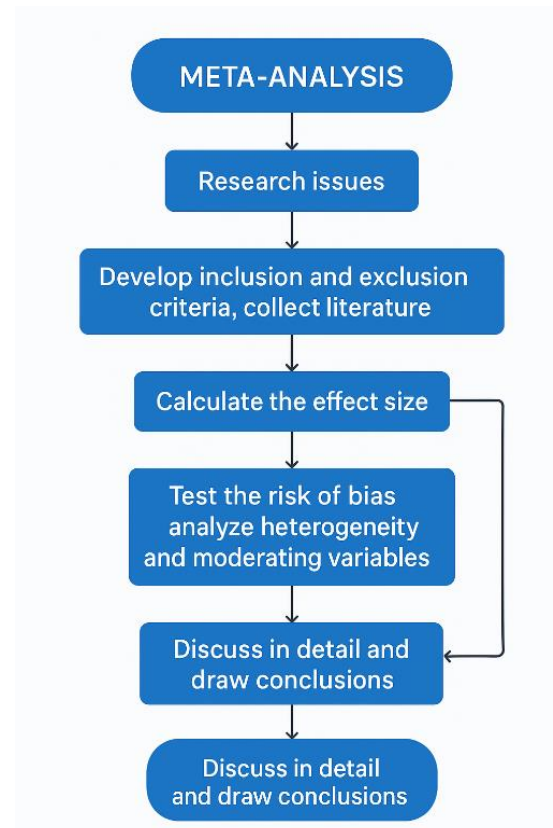

Fig 1: The Research Framework

Literature Search

The researcher conducted a systematic literature search to identify relevant articles about the influence of the Inquiry-Based Learning (IBL) learning model on students' critical thinking skills. The search was focused on one international scientific database, Scopus, as it provides a collection of reputable academic journals relevant and verified in the field of education and learning psychology.

The search is performed using the search string: TITLE (inquiry AND critical AND thinking) AND (LIMIT-TO(DOCTYPE, "ar")) AND (LIMIT-TO(LANGUAGE, "English")). The keyword is designed to find articles that explicitly list key terms in the title. The researcher only included articles in the form of journal articles and written in English to ensure the validity and comparability of the data.

The researchers established five inclusion criteria to filter out relevant articles. Included articles must explicitly include the terms Inquiry-Based Learning and critical thinking, report on the results of quantitative research, use experimental or quasi-experimental design, be available in full text versions, and be written in English. The researcher also searched the bibliography of the selected articles to find additional references that might be relevant. This process generates an initial number of articles, which are then further screened.

Researchers evaluate each article based on its title, abstract, method, and results section. Articles that did not empirically test the influence of IBL on critical thinking skills were excluded. Literature review articles, theoretical articles, qualitative studies, and studies that do not report sample size or statistical data, such as standard deviation, t, F, or p-value, are also excluded from the analysis. Studies using a single-group pretest-posttest or survey design without a comparison group were also excluded. This procedure resulted in 23 articles that met the selection criteria and provided 23 independent effect measures to be analyzed in this study, as shown in PRISMA Figure 2.

Participants and Sampling

In the meta-analysis, there are no specific rules or requirements regarding the number of literature articles; however, the selection was adjusted to focus on literature articles related to the keyword learning inquiry, resulting in 23 articles. The analyzed study involved a total of 23 articles published between 2016 and 2025. Participants included students from various educational levels, ranging from elementary school to college. The total number of participants from all studies who met the inclusion criteria was approximately 2,500 students. The sample size of each study ranged from 21 to 103 participants per group. All participants were research subjects from either the experimental group, which used the IBL learning model, or the control group, which used the non-IBL learning method.

Inclusion and Exclusion Criteria

Inclusion criteria are established to ensure that only studies relevant to the analysis and meeting the quality standards are included. Studies should use experimental, quasi-experimental, or pretest-posttest designs that explicitly implement the IBL model. Studies should also measure critical thinking skills as a primary dependent variable, and provide quantitative data that contain information allowing for the calculation of effect sizes (e.g., mean, standard deviation,

t-value, F-value, or p-value). Participants in the study must be from primary, secondary, or higher education.

In contrast, studies that are qualitative or descriptive, without quantitative data, those that do not focus on critical thinking skills, articles that only describe the IBL model without outcome measurement, as well as previous literature reviews or meta-analysis articles, are excluded from the analysis process.

Coding Schema

The researcher established a variable coding scheme for each selected article based on the theoretical framework and focus of the meta-analysis study. The encoded variables included the type of Inquiry-Based Learning approach, the critical thinking construct measured, the type of critical thinking assessment instrument, the role of the teacher in the experimental group, the kind of instruction of the control group, the duration of the intervention, the level of education of the participants, the country of origin of the research, the year of publication, the type of publication, the name of the author, and the sample size which can be seen in table 1.
The types of IBL are categorized into two kinds, namely guided inquiry and open inquiry. The guided approach places the teacher as a facilitator who provides the initial structure, while the open approach allows students to design the entire investigation process independently. Critical thinking constructs are grouped into two categories based on Facione (1990), namely skill-based and disposition-based. Measurement instruments are coded as original (compiled by researchers), validated (has been tested for validity in other studies), or standardized (using standard tools such as CCTST, WGCTA, or CCTDI).

The role of teachers in the experimental group was recorded based on the presence of instructional assistance, with a code of "yes" indicating the presence of the aid and "no" indicating complete independence. The types of instruction in the control group were categorized as active (e.g., guided discussions or experiments), passive (such as lectures), mixed, or no intervention. The duration of the intervention was recorded in minutes as a continuous variable.
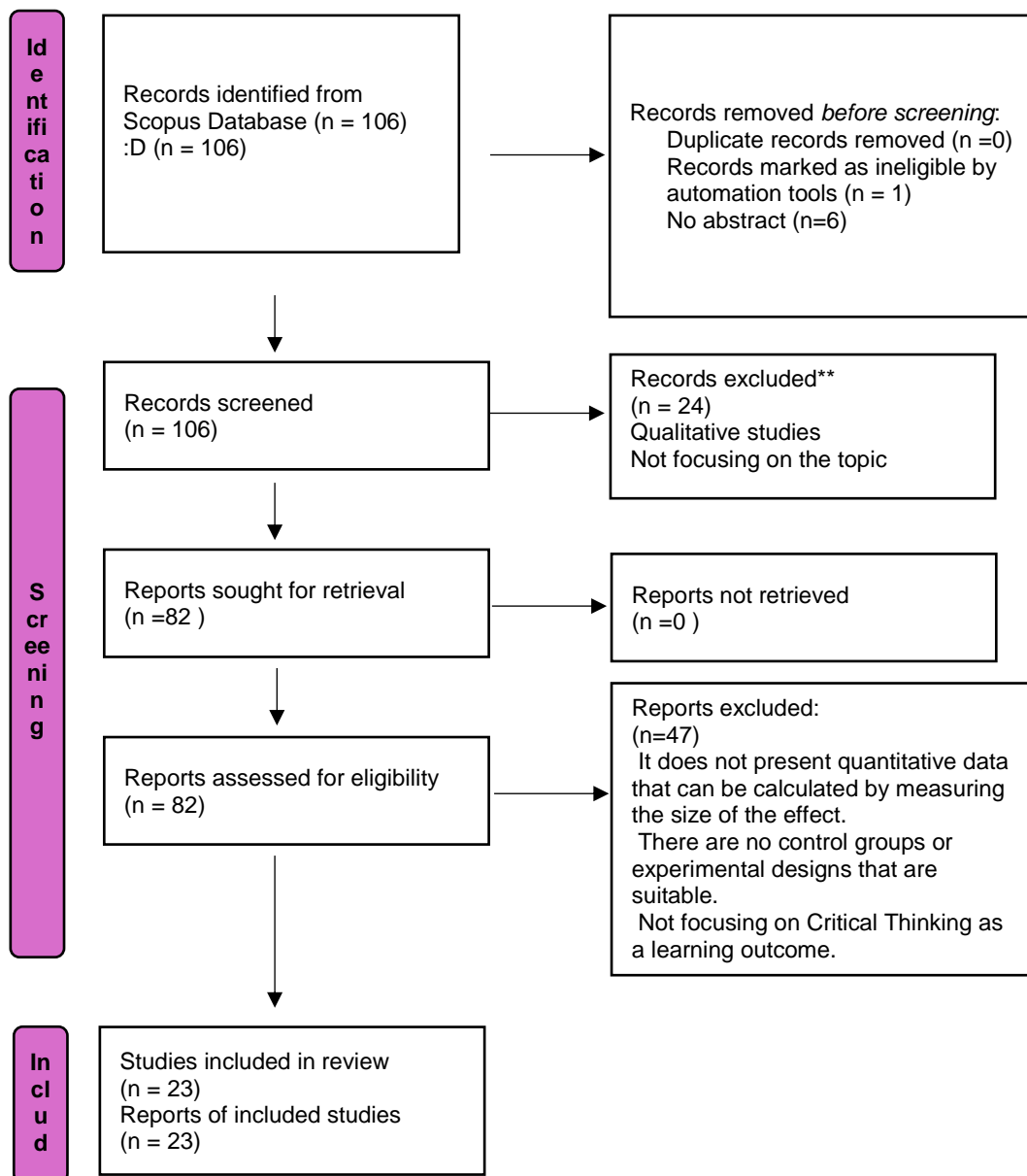
Fig 2: Flow Diagram PRISMA Inquiry on Critical Thinking

Table 1: Studies Included in this meta-analysis

Study Name	Year	Types of Inquiry	Critical thinking category	Instrument Type	The role of teachers
(Aditya et al., 2022)	2022	guided inquiry	Skill Based	Validated	active
(Yasa et al., 2024)	2024	guided inquiry	Skill Based	Validated	active
(Hwang & Chen, 2017)	2017	guided inquiry	Skill Based	Validated	active
(Hairida, 2016)	2016	guided inquiry	Skill Based	Validated	active
(Irwanto, 2023)	2023	guided inquiry	Skill Based	Validated	active
(Duran & Dökme, 2016)	2016	guided inquiry	Skill Based	Validated	active
(Harjono et al., 2025)	2025	guided inquiry	Skill Based	Validated	active

(Wahyudi et al., 2019)	2019	guided inquiry	Skill Based	Validated	active
(Putu Verawati et al., 2022)	2022	guided inquiry	Skill Based	Validated	active
(Rafiq et al., 2023)	2023	guided inquiry	Skill Based	Validated	active
(Prayogi et al., 2023)	2023	guided inquiry	Skill Based	Validated	active
(Prayogi et al., 2024)	2024	guided inquiry	Skill Based	Validated	active
(Sari et al., 2021)	2021	guided inquiry	Skill Based	Validated	active
(Perdana et al., 2020)	2020	guided inquiry	Skill Based	Validated	active
(Prayogi et al., 2022)	2022	guided inquiry	Skill Based	Validated	active
(Low, 2024)	2024	guided inquiry	Skill Based	Validated	active
(Suwono et al., 2023)	2023	guided inquiry	Skill Based	Validated	active
(Irwanto et al., 2019)	2019	guided inquiry	Skill Based	Validated	active
(Van Brederode et al., 2020)	2020	guided inquiry	Skill Based	Validated	active
(Wale & Bishaw, 2020)	2020	guided inquiry	Skill Based	Validated	active
(Lu et al., 2019)	2019	guided inquiry	Skill Based	Validated	active
(Dewi et al., 2021)	2021	guided inquiry	Skill Based	Validated	active
(Yuliarti et al., 2023)	2023	guided inquiry	Skill Based	Validated	active

Meta Analysis Process

This meta-analysis aims to determine the overall effect size of the Inquiry-Based Learning (IBL) learning model on students' critical thinking skills. The analysis process involves calculating the size of the aggregate effect and testing the moderator variables based on the study's characteristics. The researcher used Comprehensive Meta-Analysis (CMA) software, version 3.3, to calculate the effect size and execute the entire statistical procedure.

The effect size calculation was performed using Hedges' g as a correction for the standard effect size in small samples. The researcher calculated the standardized mean difference using sample size, mean value, and standard deviation data in each group.

Homogeneity tests were performed to assess the extent to which the effect sizes between studies were uniform or heterogeneous. The results of the Q test showed significant values ($Q = 515.68$; $p < 0.001$), and the I^2 index exceeded 75%, indicating a high degree of heterogeneity between studies. Therefore, the researcher used a random-effects model to calculate the size of the aggregate effect and proceeded to the moderator analysis stage. For moderators in the form of categorical variables such as education level and type of inquiry, the researcher used a subgroup analysis technique. For continuous moderator variables such as sample size and year of publication, the researchers used meta-regression.

The researchers also tested for the possibility of publication bias using funnel plots and fail-safe number calculations. The results of the plot funnel visualization showed an asymmetrical pattern of effect distribution, while the fail-safe number value did not exceed the minimum limit of 5k + 10 (with k = number of studies), indicating a potential publication bias (Rothstein et al., 2005). To adjust the bias, the researcher applied the trim-and-fill method. However, the researchers also consider that this method may result in false corrections in the event of extreme variability between studies or when the relationship between sample size and effectiveness is inverse. Therefore, selection modelling is used as an additional approach to adjust for the possibility of publication bias, as recommended (Terrin et al., 2003).

4. Result

Descriptive Statistics

A total of 23 articles published between 2016 and 2025 resulted in 23 independent effect measures; about 2,500 participants were involved; sample sizes varied between 21 and 103 participants per group; and the effect size ranges from 0.000 to 9.817. As shown in the forest plot (Figure 2), the two studies produced substantial effect sizes (exceeding 8.0), which are likely statistical outliers (Prayogi et al., 2022, 2023, 2024; Verawati et al., 2022).

Homogeneity Test and Effect Size

The homogeneity test revealed significant heterogeneity between studies (Q = 515.68; p < 0.001), supporting the use of a random-effects model. The results of the random-effects analysis showed that inquiry-based learning had a large and significant influence on improving students' critical thinking skills, with Hedges's g of 2,737 (95% CI [2,075, 3,398]; z = 8,110; p < 0.001). These findings suggest that the inquiry approach is consistently effective across a wide range of studies.

Sensitivity Analysis

To ensure the resilience of the meta-analysis results to the influence of studies with extreme effect sizes, sensitivity analysis was performed by removing five studies identified as outliers. These studies include works of (Prayogi et al., 2022, 2023, 2024; Verawati et al., 2022). These studies showed very large effect sizes (Hedges's g > 8), thus potentially distorting the overall aggregate estimate. After the elimination of the six studies, the results of the analysis using the random-effects model still showed that inquiry-based learning had a large and statistically significant influence on students' critical thinking skills, with (Hedges's g = 2,737; 95% CI [2,075, 3,398]; p < 0.001), indicating that the results of the meta-analysis were robust and did not rely on studies with extreme effects.

These findings indicate that the results of the meta-analysis are robust and are not entirely influenced by studies with extreme effects, thus supporting the validity of the overall conclusions.

Bias Publications

Publication bias analysis was performed using the plot funnel, Egger regression test, and Duval and Tweedie's trim and fill method. The funnel plot shows a pattern of asymmetry, which is

reinforced by the results of Egger's test with an intercept value of 10.22 (p < 0.001), indicating an indication of publication bias. The trim and fill analysis estimated that there were 6 unreported studies (missing studies). After adjustment, the effect size decreased from g = 2.009 to g = 1.028 (CI: 0.393 to 1.663), but remained statistically significant.

These results suggest that despite indications of publication bias, the effectiveness of inquiry-based learning in improving critical thinking skills remains substantial and statistically valid.

Moderator Analysis

The researcher conducted a moderator analysis to assess the stability of the inquiry-based learning effect measure on students' critical thinking skills. This step was taken after significant heterogeneity was found between studies, as indicated by the high Q value and I^2 index. This analysis aims to identify the possibility of study variables that contribute to effect variation, as well as ensure that the findings are consistent and reliable.

The moderator evaluation was conducted based on an approach relevant to the type of data being analyzed, i.e. using the Hedges's effect measure g in experimental studies. The results of this analysis provide methodological support in strengthening the validity of the overall meta-analysis results which can be seen in Figure 3, Figure 4 and Table 2

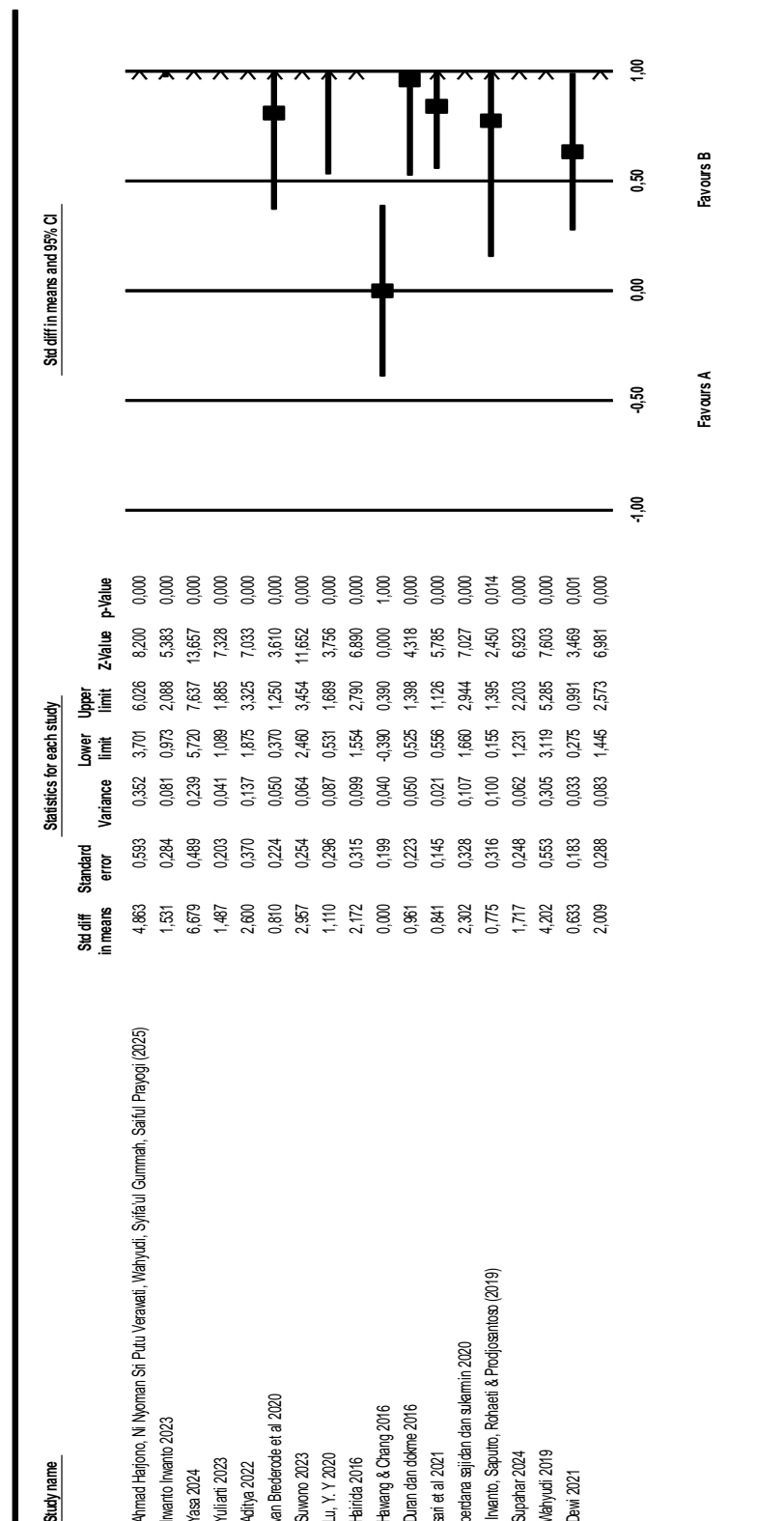| Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Ahmad Harjono, Ni Nyoman Sri Putu Verawati, Wahyudi, Syifaul Gummah, Saiful Prayogi (2025)	4,863	0,593	0,352	3,701	6,026	8,200	0,000
Irwanto Irwanto 2023	1,531	0,284	0,081	0,973	2,088	5,383	0,000
Yasa 2024	6,679	0,489	0,239	5,720	7,637	13,657	0,000
Yuliarti 2023	1,487	0,203	0,041	1,089	1,885	7,328	0,000
Aditya 2022	2,600	0,370	0,137	1,875	3,325	7,033	0,000
van Brederode et al 2020	0,810	0,224	0,050	0,370	1,250	3,610	0,000
Suwono 2023	2,957	0,254	0,064	2,460	3,454	11,652	0,000
Lu, Y. Y 2020	1,110	0,296	0,087	0,531	1,689	3,756	0,000
Hairida 2016	2,172	0,315	0,099	1,554	2,790	6,890	0,000
Hwang & Chang 2016	0,000	0,199	0,040	-0,390	0,390	0,000	1,000
Duran dan dokme 2016	0,961	0,223	0,050	0,525	1,398	4,318	0,000
sari et al 2021	0,841	0,145	0,021	0,556	1,126	5,785	0,000
perdana sajidan dan sukarmin 2020	2,302	0,328	0,107	1,660	2,944	7,027	0,000
Irwanto, Saputro, Rohaeti & Prodjosantoso (2019)	0,775	0,316	0,100	0,155	1,395	2,450	0,014
Supahar 2024	1,717	0,248	0,062	1,231	2,203	6,923	0,000
Wahyudi 2019	4,202	0,553	0,305	3,119	5,285	7,603	0,000
Dewi 2021	0,633	0,183	0,033	0,275	0,991	3,469	0,001
	2,009	0,288	0,083	1,445	2,573	6,981	0,000

Fig 3: Forest Plor for the Random-Effects Model

Table 2: Random-Effects Model of the Effect Inquiry on Critical Thinking: A Key to Understanding the Impact of IBL on Critical Thinking

Model	Effect size and 95% Confidence interval						Test of null (2-tail)	
Model	Number Studies	Poin Estimate	Standard error	Variance	Lower limit	Upper limit	Z-Value	P-Value
Fixed	17	1.331	0.060	0.004	1.213	1.450	22.038	0.000
Random	17	1.987	0.285	0.081	1.428	2.545	6.975	0.000
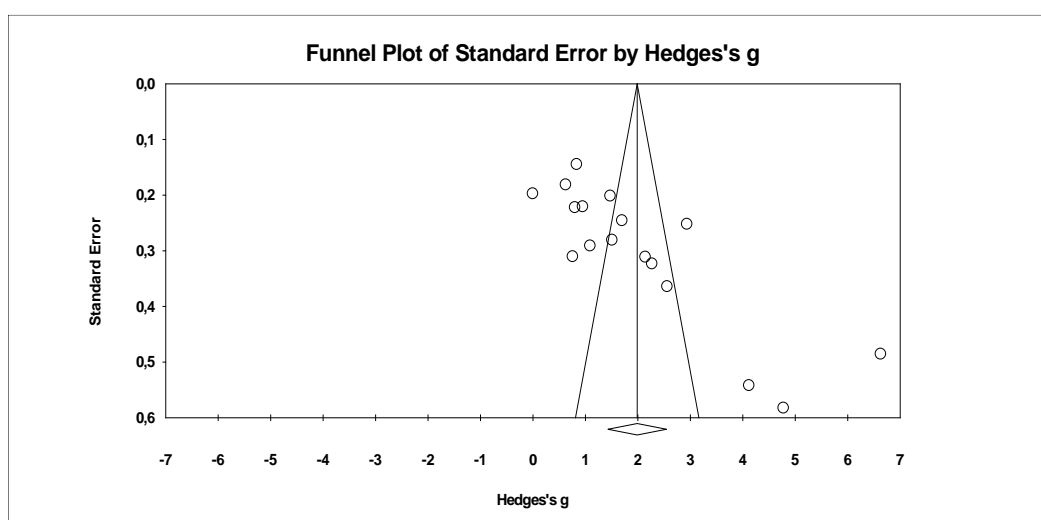
Fig 4: Funnel Plot of the Effect Sizes with 95% Confidence Interval

Meta-Correlational Analysis

The relationship between inquiry-based learning (IBL) and students' critical thinking skills has been extensively studied by researchers in various educational contexts. Findings from several studies indicate that the IBL approach can enhance students' ability to think reflectively, logically, and analytically. To ensure the consistency of these relationships, the researchers conducted a comprehensive meta-analysis of 17 relevant studies, using a measure of the correlation effect (r) and its transformation value, expressed as Fisher's Z.

Preliminary analysis using a fixed-effect model showed that inquiry-based learning had a strong and significant relationship with students' critical thinking skills. The study's results showed an aggregate correlation value of 0.693, with a 95% confidence interval ranging from 0.669 to 0.715. A Z-value of 37.189 and a p<significance of 0.001 suggest that this relationship did not occur by chance but was statistically significant and repeated in various study contexts. The researcher transformed the correlation value into Fisher's Z form to obtain a more stable and compatible effect estimate for follow-up tests such as moderator analysis and meta-regression. The transformation results showed a value of $Z = 0.853$, with a confidence interval of 0.808 to 0.898, and the exact significance ($p < 0.001$). The consistency between these two measurement approaches indicates that inquiry learning has a significant contribution to the development of critical thinking skills. A summary of the results of the correlation meta-analysis based on the fixed effects model can be seen in table 3.

Table 3: Summary of Meta-Analysis of Correlation (Fixed Effect Model)

Type	Effect Size	Lower Limit	Upper Limit	Z-Value	Sig. (p)
Correlation	0.693	0.669	0.715	37.189	0.000
Fisher's Z	0.853	0.808	0.898	37.189	0.000

The interpretation of the table shows that all the studies analyzed make a positive and consistent contribution to the relationship between inquiry approaches and students' critical thinking skills. Almost all of the confidence intervals of each study did not intersect with zero, indicating the existence of a statistically significant relationship.

These findings align with the perspective of social and cognitive constructivist theories, which view students as active subjects in constructing their knowledge. In the inquiry approach, the learning process, which emphasizes inquiry, exploration, and reflective dialogue, creates an environment that opens up space for learners to develop their thinking schemas. This refers to Piaget's framework of assimilation and accommodation, which states that new learning stimuli will trigger the reorganization of cognitive structures through the process of adaptation. When learners are given the challenge of asking questions, investigating, and drawing conclusions on their own, their critical thinking skills are not only trained but also naturally developed through the learning experience itself. Therefore, inquiry-based learning approaches can be positioned as a relevant and contextual strategy in answering the challenges of developing critical thinking skills in the 21st century, inspiring educators, researchers, and policymakers to apply these findings in their work.

Impact of IBL on Critical Thinking

Researchers found that inquiry-based learning has a significant influence on students' critical thinking skills. The analysis of the results in Table 5 shows that the correlation value of 0.693 with a significance value of $p = 0.000$ is well below the threshold of 0.05. These results indicate that the relationship between the application of the inquiry model and the improvement of critical thinking is statistically strong and consistent.

The researchers confirmed the findings through Fisher's Z transformation, which yielded a combined effect value of 0.853 with a significance value of $p = 0.000$. The consistency of these results shows that inquiry learning tends to encourage students to form a reflective, analytical, and evaluative mindset.

Our findings confirm that inquiry-based learning is not just an instructional approach, but a powerful cognitive strategy. IBL plays a crucial role in enabling the reorganization of students' thinking schemas. The process of questioning, exploring, and inferring in IBL fosters a mental state that encourages the development of a deeper knowledge structure, a process that, according to Piaget, occurs through the interplay of assimilation and accommodation. Therefore, IBL can be considered a fundamental approach in efforts to improve critical thinking skills in the 21st-century learning environment.

5. Discussion

Inquiry-based learning has a significant influence on students' critical thinking skills, as shown by the results of the meta-analysis, which showed a correlation value of 0.693 with a p-value of < 0.001. These findings were reinforced by Fisher's Z transform value of 0.853, indicating a strong and consistent relationship between the application of IBL and improved critical thinking. Additionally, students who studied using the inquiry model demonstrated a significant improvement in critical and analytical thinking skills compared to conventional learning methods, as evidenced by a substantial increase in pretest-posttest scores in various field studies. The findings in the analysis also suggest that inquiry-based learning encourages students to actively ask questions, discuss, and explore, thereby increasing their confidence in finding knowledge and solutions to the problems they face. These findings suggest that the IBL approach is not only an instructional method but also a cognitive strategy that allows for a reflective and evaluative reorganization of students' thinking schemas.

The critical thinking indicators, as formulated, include six components: interpretation, analysis, evaluation, inference, explanation, and self-regulation. Each of these indicators is influenced by the other. For example, the activity of interpreting observed phenomena stimulates the development of interpretation skills. The process of evaluating arguments based on evidence encourages the strengthening of evaluation indicators. The exploratory activities and hypothesis submission that are at the core of inquiry develop inference skills. The elaboration of the investigation's results by students hones their explanations, while reflection on the learning process and results strengthens their self-regulation. This comprehensive influence of IBL on critical thinking indicators underscores its effectiveness in promoting a holistic development of students' critical thinking skills.

These processes demonstrate a close relationship with Piaget's theory of cognitive constructivism and the theory of proximal zone development (Vygotskij & Cole, 1981). Piaget emphasized that cognitive development occurs through a process of assimilation and schematic accommodation triggered by cognitive conflict. In the context of IBL, when learners encounter challenging situations and do not yet possess the appropriate cognitive structure, they form new schemas through accommodation. This aligns with the opinion Duran and Dökme (2016) that IBL can create productive cognitive conflicts to stimulate the reorganization of knowledge. Meanwhile, Vygotsky's theory underscores the importance of social interaction and scaffolding in the learning process. In IBL, the role of the teacher as a facilitator who provides temporary assistance is part of the critical thinking process that develops in the student's proximal zone. Research Irwanto (2023) also showed that the IBL model had a positive influence on all critical thinking indicators, with the highest increase in the aspects of analysis and inference. This indicates that inquiry encourages learners not only to receive information, but also to compare, analyze, and draw logical conclusions.

When compared to other learning models such as Problem-Based Learning (PBL), the IBL model has been effective in developing critical thinking skills in groups of students with low ability levels (Darhim et al., 2020; Hürsen, 2020; Plummer et al., 2022; Scott, 2021; Yeung et al., 2023). Duran and Dökme (2016) Notes that IBL has the advantage of providing an open exploration space, while PBL focuses more on practical problem-solving with more structured instruction. In addition, the results of a study conducted Dewi et al (2021) showed that inquiry learning was more successful in improving critical thinking skills in prospective teachers with converging learning styles than PBL.

The relationship between IBL and critical thinking can be understood from the perspective of Piaget's theory, specifically the concepts of assimilation and accommodation. The IBL process, which encourages learners to question, explore, and infer for themselves, creates cognitive conditions that stimulate the formation of new schemas. This aligns with the statement that the inquiry approach encourages students' active participation in developing a meaningful and in-depth understanding of science. Meanwhile, Vygotsky's basic principles of learning in social contexts are also reflected in the practice of inquiry through group work, discussion, and question-and-answer sessions, which place social interaction as a lever for the development of critical thinking.

Although the results of the meta-analysis showed strong effectiveness of IBL, the study had some limitations. First, not all studies report results per critical thinking skill indicator. Second, the potential for publication bias is detected through the plot funnel test and Egger's test. Third, some studies reveal extreme effect sizes that require correction through sensitivity analysis. Therefore, further research is recommended to explore the role of each IBL indicator in more detail, considering variations in educational contexts and the role of teachers in learning facilitation.

Implication

The theoretical findings obtained from this meta-analysis highlight the need to revisit the assumptions underlying the typology of learning guides. The conceptual framework used was developed based on a review of the current literature on inquiry-based learning and was implemented for the first time in this meta-analysis. The framework has proven to be effective in grouping the various forms of guidance used in previous research based on a single dimension, but assumptions about the suitability of the type of guidance with the initial level of knowledge and skills of learners are not entirely in line with the current findings.

Although there is an effect of moderation on performance success, learning activities, and learning outcomes, all types of guidelines show a positive contribution. These findings indicate that a more general form of guidance still provides benefits for learners who still have limited questioning skills, while more experienced learners benefit more from active forms of guidance. This opinion is in line with Irwanto (2023) which explains that meta-analysis is a new insight to be used as material for reflection and further development in the future literature to refine the typology of inquiry-based learning guides.

The implications of these findings suggest that IBL deserves to be adopted more widely in 21st-century learning curricula. This model contributes not only to the cognitive aspect but also to the strengthening of a critical thinking disposition that is reflective, systematic, and open to new ideas. Teachers need to receive specialized training to develop effective IBL facilitation skills, accommodating the diverse learning styles and backgrounds of students, while ensuring that all critical thinking indicators are optimally stimulated during the learning process. In line with the opinion of Prayogi et al. (2023)that teachers must receive special training to deepen their knowledge so that later when applying they can become competent facilitators in their skills.

Findings in the field suggest that IBL is suitable for adoption in 21st-century curricula, offering researchers valuable insights. As active educators in this century, it is necessary to receive training related to IBL-based learning techniques, enabling them to address challenges and difficulties in their implementation. Another suggestion is aimed at unit holders or other

educational institutions to integrate special programs related to IBL training and monitor their implementation so that it can be measured concretely. The researcher also provides guidance to researchers in the field of curriculum development, suggesting they explore similar research with different variables to obtain diverse research results.

Limitations

The study has several technical limitations that need to be considered when interpreting the results. Not all primary studies present detailed data based on individual critical thinking skill indicators, so the analysis focuses more on the size of the aggregate effect. The heterogeneity between studies is quite high, so caution is needed when concluding about different educational contexts. Publication bias analysis reveals potential imbalances in the distribution of studies; However, adjustments using the trim and fill method still produce significant results. Variations in research design, teacher roles, and instrument types across studies can also moderate the influence on outputs. Therefore, the results of this study can be a solid basis for more in-depth follow-up studies in specific contexts and for more focused critical thinking indicators.

Conclusion

This study aims to present a comprehensive synthesis of research published between 2016 and 2025 on the effectiveness of Inquiry-Based Learning (IBL) in improving students' critical thinking skills. The meta-analysis highlights key findings that confirm the significant role of IBL in activating students' cognitive processes such as analysis, inference, and evaluation across various educational levels and contexts. The findings also support the robustness of the results after adjustments for sensitivity and publication bias.

Inquiry-based learning has consistently shown effectiveness as both a pedagogical method and a cognitive strategy for fostering reflective and analytical thinking. Students involved in IBL environments are more likely to engage in inquiry, actively construct knowledge, and develop a deeper understanding through dialogic and investigative learning experiences. Theoretical foundations, such as Piaget's assimilation-accommodation and Vygotsky's zone of proximal development, provide meaningful explanations of how IBL facilitates the development of critical thinking through both individual and social learning mechanisms.

While the meta-analysis provides strong evidence of IBL's benefits, it also acknowledges the variation in implementation strategies and the limited reporting of effect sizes per specific critical thinking indicator. These aspects suggest opportunities for further investigation. Future studies should investigate how different forms of IBL impact each essential component of thinking, explore the role of teacher facilitation, and examine cultural and contextual differences across various educational settings.

These insights lay the groundwork for the broader application of Inquiry-Based Learning in 21st-century curricula. By deepening their understanding of how IBL supports cognitive growth, educators and policymakers can design more responsive instructional models that promote critical reasoning and equip students with the essential skills needed to navigate complex learning environments.

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