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REALIZING 21ST CENTURY LEARNING THROUGH INQUIRY-BASED LEARNING: A META-ANALYSIS

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Abstract

Throughout history, curiosity has driven individuals to explore and understand the essence of their existence. Inquiry-Based Learning (IBL) has emerged as a highly effective teaching method that empowers students to actively engage in the learning process, identify real-world problems, generate diverse solutions, and significantly enhance their learning experiences. This meta-analysis evaluates the effectiveness of IBL in fostering 21st-century skills such as critical thinking, problem-solving, and creativity. Using a systematic approach, articles from 2015 to 2024 were collected and analyzed through the PRISMA methodology, involving identification, screening, eligibility assessment, and inclusion. Sixteen primary studies meeting the inclusion criteria were analyzed using Hedge's random effects model. Results indicate that IBL significantly improves student outcomes, with an average effect size of 0.69, categorized as medium. Heterogeneity analysis showed significant variation among studies ($Q = 47.849$, $p < 0.001$). The Forest Plot demonstrated a statistically significant positive effect, while the Funnel Plot and Rosenthal's fail-safe N test indicated no publication bias, affirming the reliability of the results. IBL promotes active student participation through exploration, questioning, and real-world experiences, which are essential in 21st-century education. This meta-analysis underscores the substantial positive impact of IBL on student learning outcomes, suggesting its integration into curricula to enhance student skills in critical and creative thinking, thereby improving the quality of education globally. The findings advocate for professional development and innovative teaching approaches to meet evolving educational needs.

Keywords: Inquiry-Based Learning, Critical Thinking, Problem-Solving, Creativity, Meta-Analysis, 21st-Century Skills.

INTRODUCTION

Throughout history, curiosity has driven individuals to explore and comprehend the essence of their own existence. From birth to the end of life, this process of learning not only reflects a profound sensitivity and enthusiasm but also represents a continuously evolving journey, prompting a deeper investigation and expansion of knowledge about the world and oneself [1].

The intrinsic human nature of curiosity and the urge to discover new things propel individuals to question everything, aiding in better decision-making and honing critical thinking skills. One of the key aspects of this is lifelong learning. To achieve this goal, individuals must actively engage in learning environments, analyzing, discovering, researching, and posing questions. Active participation in learning fosters the retention of knowledge and supports the overall learning process [2] [3].

Inquiry-Based Learning emerges as a highly effective teaching method that empowers students to actively engage in the learning process, identify real-world problems, generate diverse solutions, and significantly enhance their learning experiences. In this approach, students develop their own hypotheses and test them meticulously [4] [5].

This learning model encourages students to actively question, critique, think creatively and reflectively, and solve problems, while simultaneously developing their skills and deepening their understanding.

With the growing interest in Inquiry-Based Learning, numerous studies have been conducted to evaluate its effectiveness in improving student learning outcomes. The implementation of the IBL model involves a distinct syntax or stages compared to traditional methods.

This model encompasses several critical steps: formulating questions and hypotheses, selecting and applying methods, and examining and presenting results [6]. This approach can be challenging, particularly for younger learners [7]. The application of the IBL model is crucial for enhancing critical thinking skills and academic performance. Research has shown that IBL fosters critical thinking abilities, enabling individuals to solve problems from various perspectives [8] [9].

This aligns with the expectations of 21st-century education, where fostering essential skills such as critical thinking, problem-solving, and creativity is paramount [10] [11] [12]. Inquiry-Based Learning has demonstrated a positive impact on student achievement and the development of 21st-century skills. Therefore, promoting IBL through professional development and innovative teaching approaches is essential to meet the evolving educational needs of the 21st century.

According to Borkowski [13], Inquiry-Based Learning (IBL) is a strategy within the constructivist approach to education. It actively involves students in posing questions, exploring topics, and developing critical thinking skills by focusing on "how to think" rather than "what to think" [14]. As a highly effective teaching method, Inquiry-Based Learning empowers students to actively engage in the learning process, identify real-world problems, generate diverse solutions, and significantly enhance their learning experiences [15].

This article presents the results of a meta-analysis of studies conducted on Inquiry-Based Learning (IBL). The primary focus of this analysis is to evaluate the extent to which IBL can realize 21st-century learning and contribute to its successful implementation. The findings from this meta-analysis are expected to provide significant contributions to the development of educational theory and practice, particularly in the context of inquiry-based learning in Indonesia and globally.

METHODOLOGY

This research is a meta-analysis that compiles articles on similar topics from various sources and summarizes the results using statistical methods [16]. The main focus of this study is to explore how the Inquiry-Based Learning model can enhance students' critical thinking skills, Higher-Order Thinking Skills (HOTS), problem-solving, and creativity.

Data sources for the articles were obtained from Google Scholar, ScienceDirect, and ERIC, which are all search engines connected to various sources of articles worldwide. Thus, the breadth of data obtained is extensive and minimizes potential bias in the data.

The articles to be analyzed in this meta-analysis include publications from 2015 to 2024, using keywords such as "Inquiry-Based Learning, critical thinking skills, Higher-Order Thinking Skills, problem-solving, and student creativity."

The process of searching for relevant articles was conducted using the PRISMA method (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), which consists of four stages: identification, screening, eligibility assessment, and inclusion. The PRISMA method is effective for conducting meta-analyses because it provides systematic selection steps for the chosen articles [17].

The data analysis methodology in this research employs a meta-analytic approach using the random effects model with Hedge's g. According to the requirements of this model, the collected data must be heterogeneous.

Data were gathered and analyzed from the identified publications to determine the effect size (d), Standard Error (SEg), Mean (M), Standard Deviation (SD), and sample size (n). Articles selected for the meta-analysis must meet the inclusion criteria, and the data extracted must align with the data specified in the research inclusion criteria.

After determining the effect size and standard error, the data were analyzed using the statistical software JASP. This software facilitates meta-analysis on the collected articles. JASP aids in determining the bias values of the reviewed papers and in analyzing heterogeneity in the meta-analysis, effect sizes, and the range of minimum/maximum effect sizes.

Consequently, conclusions from the meta-analysis can be drawn. The classification of Effect Size Cohen's based on Rosenthal & Rubin [18] is as follows.

Table 1: Cohen's Effect Size Classification

Effect Size	Kategori
0 ≤ES≤ 0,2	Low Effect
0,2 ≤ ES≤ 0,8	Medium Effect
ES ≥ 0,8	High Effect

RESULTS AND DISCUSSION

A total of 200 primary studies were identified from various sources such as Google Scholar, Semantic Scholar, ERIC, Science Direct, IOP Science, and Atlantis Press. However, 40 primary studies with similar titles were excluded during the screening process. After screening the abstracts, we found that 30 primary studies were not relevant, leaving 130 primary studies eligible for the eligibility phase.

Considering the inclusion criteria, we found that 54 primary studies did not report complete statistical data, while 48 primary studies did not involve conventional learning or control classes as comparison groups. After the initial phase, 28 articles met the preliminary criteria for this meta-analysis. However, these articles still had to pass the final selection stage to ensure that the necessary data were presented completely in each article.

A total of 16 publications met the criteria for research data, including mean (M), standard deviation (SD), and the number of participants (n) from both control and experimental classes. The summary of the obtained articles is presented in the following table.

Table 2: Recapitulation of Meta-Analysis Articles

Article code	Experiment			Control			Effect Size	Standard Error (SE)
	N	M	SD	N	M	SD		
code 1 [19]	32	78,05	8,11	32	68,38	12,042	0.94	2,542
code 2 [20]	47	13,021	2,345	44	11,023	3,534	0.67	0,591
code 3 [21]	40	67,76	17,8	38	39,57	10,905	1.90	3,22
code 4 [22]	32	63,53	8,88	32	54,47	9,42	0.99	2,146
code 5 [23]	26	7,54	4,4	30	11,37	5,42	-0.77	1,173
code 6 [24]	27	80,55	7,58	28	71,11	7,78	1.23	2,083
code 7 [25]	30	18,111	6,05	30	12,2	7,857	0.84	1,77
code 8 [25]	13	21,467	11,262	15	17,231	12,125	0.36	4,358
code 9 [25]	30	8,333	5,172	30	6,1	4,677	0.45	1,044
code 10 [25]	13	7	3,78	15	5	1,78	0.69	1,097
code 11 [26]	80	0,53	0,83	81	0,57	0,79	-0.05	0,138
code 12 [26]	80	1,11	1,23	81	0,14	0,38	1.07	0,168
code 13 [26]	80	0,78	1,02	81	0,25	0,46	0.67	0,148
code 14 [26]	80	1,15	1,05	81	0,14	0,38	1.28	0,168
code 15 [27]	25	70,8	5,94	25	66,8	6,48	0.64	1,731
code 16 [27]	25	71,4	4,95	25	67,6	5,05	0.76	1,68

The data collected from 16 major studies have been compiled and presented in Table 2. This table provides a comprehensive overview of relevant research findings, encompassing various variables and key outcomes. Additionally, the characteristics of each major study are discussed in detail in Table 3. This table provides in-depth information on the Effect Size and Standard Error of the primary data, enabling a more detailed analysis of the variability and reliability of the results.

By reviewing these two tables, researchers can gain a deeper understanding of the topic under investigation. Table 2 provides an overview of the findings, while Table 3 offers additional context through methodological and statistical details of the studies included in the meta-analysis. Overall, this analysis provides a more comprehensive and thorough insight into the research findings, and assists in evaluating the effectiveness and consistency of the results obtained.

Table 3: Characteristics of Each Primary Study

Article code	Effect Size	Effect Size Category
code 1	0.94	High Effect
code 2	0.67	Medium Effect
code 3	1.90	High Effect
code 4	0.99	High Effect
code 5	-0.77	Low Effect
code 6	1.23	High Effect
code 7	0.84	High Effect
code 8	0.36	Medium Effect
code 9	0.45	Medium Effect
code 10	0.69	Medium Effect
code 11	-0.05	Low Effect
code 12	1.07	High Effect
code 13	0.67	Medium Effect
code 14	1.28	High Effect
code 15	0.64	Medium Effect
code 16	0.76	Medium Effect

The analyzed data indicate that out of 16 articles, 8 articles have a high effect size, 6 articles have a medium effect size, and 2 articles have a low effect size. Articles with high effect sizes have an average value of 1.15, indicating that the studied variable has a significant impact. Articles with medium effect sizes have an average of 0.57, indicating a moderate impact, while articles with low effect sizes have an average of -0.41, indicating a small or insignificant impact. The highest effect size is 1.90 (Article 3), whereas the lowest effect size is -0.77 (Article 5). The majority of articles show significant or moderate impacts, though some articles with low impacts require further review. Overall, this data suggests that the studied intervention or variable has varying impacts, with the majority demonstrating significant or moderate effects.

1) Heterogeneity Results

The heterogeneity test aims to assess whether the applied meta-analysis model can be used effectively. The meta-analysis model used in this context is Fixed and Random Effects based on Hedges' method.

Table 4: Heterogeneity Testing

Fixed and Random Effects			
	Q	**df**	**p**
Omnibus test of Model Coefficients	10.409	1	0,001
Test of Residual Heterogeneity	47.849	15	< 0,001

The table above presents the heterogeneity analysis in the context of a meta-analysis study. The recorded Q value of 47.849 exceeds the Omnibus test of Model Coefficients value of 10.409 at a 95% confidence level. This result indicates significant variation among the study results analyzed, signifying heterogeneity in the distribution of effects. Furthermore, the p-value of < 0.001 confirms that the differences among the study results cannot be explained solely by random variation. Therefore, it can be concluded that the distribution of effects in this meta-analysis is heterogeneous according to the fixed-effects model. In this context, the fixed-effects model suggests that no single effect can be identified based on the observed effect sizes. Instead, this variation in effects reflects the complexity of the phenomena being studied and underscores the importance of considering heterogeneity in interpreting meta-analysis results.

2) Forest Plot

The Forest Plot illustrates the distribution of effect sizes from the primary studies analyzed using a random-effects model. This plot provides a clear visualization of the variation in effect sizes among the various studies in the meta-analysis. Each bar in this plot represents the effect size of a single study, with vertical lines indicating the 95% confidence intervals. Through this plot, researchers can observe the variation in effects among the studies and identify any patterns or trends that may emerge from the data distribution. This helps researchers interpret the strength and consistency of the effects within the analyzed data set.

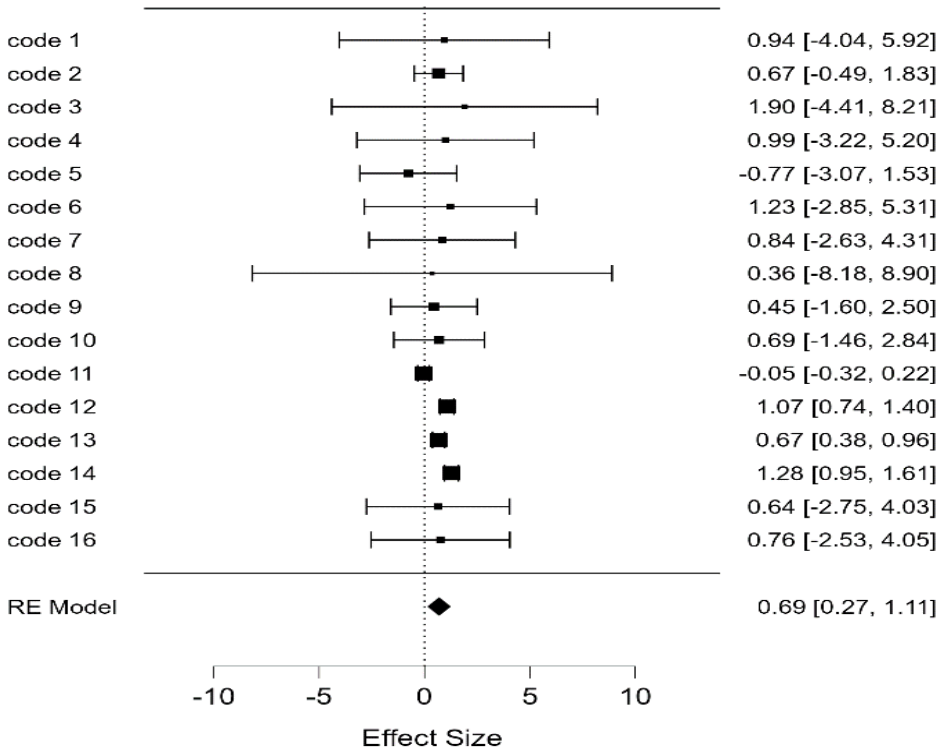

Figure 1: Forest Plot

This image presents a forest plot used in meta-analysis to display the results of several studies regarding their effect sizes. Each row in this plot represents a single study, identified by codes from code 1 to code 16. The effect size of each study is depicted with a central dot in the form of a square, and the 95% confidence interval is shown by horizontal lines. If these horizontal lines cross the vertical line at 0, the effect is not statistically significant at the 95% confidence level.

At the bottom of the plot, the overall effect size from the meta-analysis, calculated using a random effects model, is displayed with a diamond symbol. The overall effect size is 0.69, with a 95% confidence interval between 0.27 and 1.11. Since this confidence interval does not cross 0, it can be concluded that the overall effect is statistically significant at the 95% confidence level. This meta-analysis result indicates that despite the variation in effect sizes among individual studies, the overall effect produced is positive and statistically significant.

3) Results of Article Bias Testing

The articles included in this meta-analysis must be free from bias to ensure the quality of the research and avoid data manipulation. Given the number of studies incorporated into the meta-analysis, bias testing aims to reveal any data presentation errors in the studies used. In this research, the level of bias was assessed using statistical analysis methods such as the fail-safe N and funnel plots, as developed by Rosenthal. A study is considered free from bias if the fail-safe N value exceeds (5K + 10) [28], where K represents the total number of studies included in the meta-analysis. To ensure the absence of publication bias in the included articles, a total of 56 papers were evaluated in the meta-analysis.

4) Funnel Plot

The effect size of the Inquiry-Based Learning model on improving student learning outcomes, as assessed from the aspects of critical thinking skills, higher-order thinking skills, problem-solving, and student creativity, is 0.69, which indicates a Medium Effect. Based on the sufficient number of studies, it can be concluded that the analysis results have high reliability and low publication bias. Furthermore, publication bias can be evaluated using the Funnel Plot shown in Figure 2.

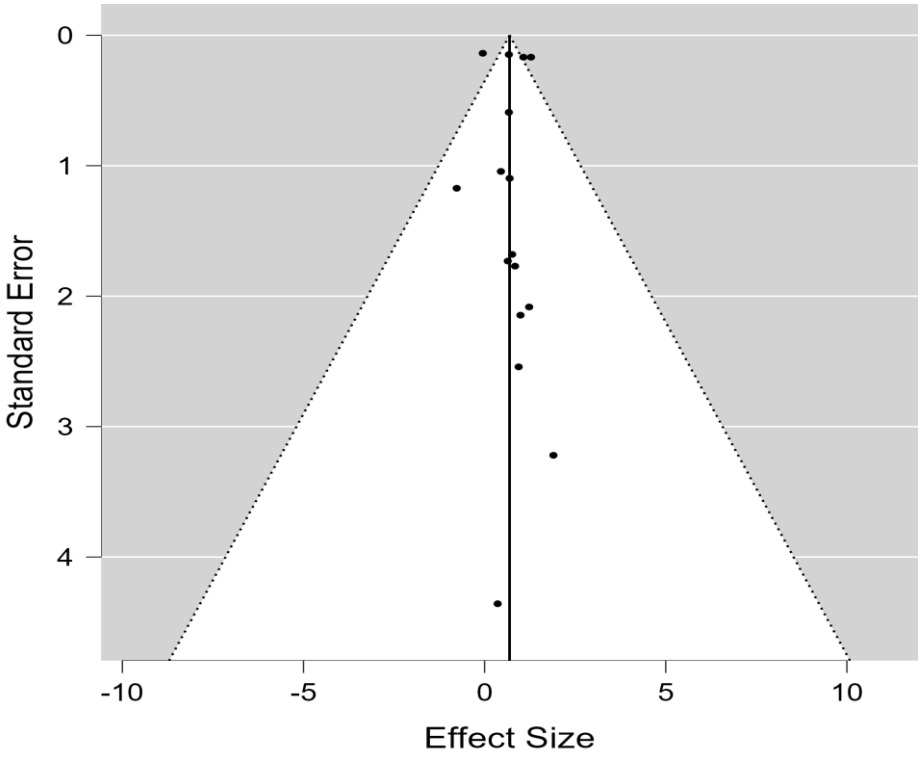

Figure 2: Funnel Plot

The funnel plot displayed illustrates the relationship between effect size and standard error across various studies in the meta-analysis. The Y-axis represents the standard error, with larger studies generally exhibiting smaller standard errors. The X-axis shows the effect size for each study, with the points on the plot representing individual studies. The vertical line in the center denotes the combined effect size of all studies, while the dashed lines forming a triangular shape indicate the 95% confidence interval.

Initial analysis of this plot reveals some asymmetry, particularly on the right side, which may suggest the presence of publication bias or variability among the smaller studies. Generally, smaller studies tend to be more dispersed, whereas larger studies are concentrated around the combined effect size line. The combined effect size approaches zero, indicating that there is no significant overall effect.

The funnel plot's symmetrical nature is clearly shown in Figure 2, illustrating the data distribution in the study. The points are evenly and symmetrically spread across both sides, confirming this observation. Additionally, the τ Kendall test results support this with a correlation coefficient of 0.126 and a p-value of 0.001, which is below the significance threshold of 0.05 ($p = 0.001 < 0.05$). These results indicate the absence of bias in the included articles, as demonstrated by the funnel plot test. To further confirm the lack of publication bias, Rosenthal's fail-safe N test was conducted. The

bias test results, shown in Table 6, reveal a fail-safe N value of 181,000, with an observed significance level below 0.001 and a significant threshold of 0.05. For K = 16, the value of (5K + 10) is calculated as 5 × 16 + 10 = 90. These findings show that N (181,000) > 5K + 10 (90) is the fail-safe value. This result further indicates no publication bias in the studies analyzed. Therefore, the conclusion that the 16 studies in the meta-analysis are free from publication bias is supported by both the funnel plot analysis and Rosenthal's fail-safe N test results.

Table 5: Results of Funnel Plot Analysis and Rosenthal Fail-Safe N Test

File Drawer Analysis			
	Fail-safe N	**Target Significance**	**Observed Significance**
Rosenthal	181.000	0.050	< .001

Inquiry-Based Learning (IBL) has been proven to significantly enhance students' critical thinking skills, problem-solving abilities, higher-order thinking skills, and foster creativity. Research indicates that IBL promotes active student participation through exploration, questioning, and real-world experiences [29] [30]. Studies show that the implementation of IBL in the curriculum has a positive impact on students' critical thinking abilities across various subjects [31], social attitudes in secondary schools, and the development of responsible character [32]. Through student engagement in collaborative writing, problem-solving tasks, and structured questioning, Inquiry-Based Learning serves as a powerful tool for developing well-rounded individuals with the cognitive skills necessary to succeed in the contemporary educational landscape [33].

CONCLUSION

The results of the meta-analysis indicate that the Inquiry-Based Learning model significantly improves student learning outcomes. This analysis includes 16 primary studies selected using the PRISMA method and analyzed with JASP software. The findings reveal an average effect size of 0.69, categorized as a medium effect. The heterogeneity analysis indicates significant variation among studies ($Q = 47.849$, $p < 0.001$). The Forest Plot demonstrates a positive and statistically significant effect, while the Funnel Plot and Rosenthal's fail-safe N test indicate no publication bias, supporting the reliability of these results. The Inquiry-Based Learning has been proven effective in enhancing students' skills through exploration, questioning, and real-world experiences, which are crucial in 21st-century education. This meta-analysis confirms that the Inquiry-Based Learning model has a significant positive impact despite variations across studies. Implementing the Inquiry-Based Learning in curricula can improve student skills, making them better prepared to face challenges and more competent in critical and creative thinking, thus supporting the enhancement of education quality in Indonesia and worldwide.

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