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ORIGINAL ARTICLE

Effects of Inquiry- based Learning Approach on Students' Critical Thinking and Creative Thinking Skills in Science: A Meta- analysis

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ABSTRACT

This study aimed to investigate the effects of the inquiry-based learning approach (IBLA) on students' critical and creative thinking skills in science. A meta-analysis was conducted on studies published from 2013 to 2023 that were retrieved from seven (7) electronic databases. A total of 29 articles out of 258, 960 articles, from the data search to document retrieval stages, met the eligibility criteria after duplicate removal and screening, and were included in the coding process. The study had a total sample size of 2,253 students. A random-effects model using forest plots generated 31 effect sizes, while publication bias was assessed using funnel plots and Rosenthal's fail-safe N. Findings revealed that the IBLA had generally produced large effect sizes of 1.59 on critical thinking skills and 2.02 on creative thinking skills, indicating substantial learning gains in comparison to conventional teaching approach. However, . variability across studies and potential methodological limitations imply that these large effects should be interpreted with caution. Fail-safe N values also showed that 4,615 unpublished studies for critical thinking skills and 1,342 unpublished studies for creative thinking skills would be needed to bring the p-value beyond the .05 threshold of significance. Overall, IBLA appears to be a highly effective approach for enhancing higher-order thinking skills in science education; however, further rigorous research is recommended to confirm the consistency and generalizability of these findings.

Keywords: *Creative Thinking, Critical Thinking, Inquiry-based Learning, Meta-analysis, Science Education.*

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INTRODUCTION

In recent decade, results from national and international large-scale assessments had reported a staggering decrease of students' performance in science. Many concerns have been raised about the ineffectiveness of the existing learning frameworks that are affected by the poor student engagement, motivation, and understanding of scientific concepts (Aidoo et al., 2022). Inadequate instruction causes the assumption that learning is boring, difficult to understand, and irrelevant to everyday life (Qamariyah et al., 2021).

Several studies suggest that students' weak performance in learning outcomes, particularly in critical and creative thinking, can be attributed to ineffective teaching strategies and challenges in the learning process (Pakpahan & Nova, 2019). Educational practices that emphasize memorization and repetition of content, rather than deeper understanding, have been found insufficient in achieving meaningful learning outcomes (Alkan, 2018).

For instance, the relatively low levels of students' critical thinking skills have been linked to instructional approaches that fail to provide adequate opportunities for intellectual growth (Susilowati et al., 2018). Similarly, findings by Suardana et al. (2019) indicate that students' creative thinking abilities remain underdeveloped, suggesting that classroom experiences may not consistently encourage the practice of such skills. This concern is particularly relevant in light of the Future of Jobs Report (2020) by the World Economic Forum, which identifies critical and creative thinking as among the most essential competencies in today's global landscape. These realities highlight the need for educational systems to adopt teaching approaches that actively promote the development of 21st-century skills and prepare learners for increasingly complex demands (Rohmah et al., 2020).

In this context, the inquiry-based learning approach (IBLA) has gained recognition for its effectiveness in enhancing student learning. Research indicates that IBLA not only improves academic outcomes but also strengthens systems thinking, engagement, motivation, and self-confidence among learners (Farah & Ayoubi, 2020). This approach involves students in active exploration, where they are encouraged to investigate questions and construct their own understanding under the guidance of the teacher (Espique & Silva, 2021).Hence, researchers have explored IBLA in science education due to its potential to encourage students to justify knowledge and gain deeper understanding of the scientific concepts. This is possible through conducting a systematic meta-analysis on IBLA. This meta-analysis is designed to produce a statistical review of previous experimental studies related to the effects of IBLA on students' critical thinking and creative thinking skills in science.

Research Questions

1. What are the post-test effects of the inquiry-based learning approach on students' critical thinking skills?
2. What are the post-test effects of the inquiry-based learning approach on students' creative thinking skills?

METHODS

Study Design

The meta-analysis approach was applied in this study. It is a systematic method that uses statistical techniques to combine results from different experimental studies to provide a sophisticated quantitative estimate of the overall effect of a particular intervention or variable on a defined outcome at a considerable time (Higgins et al., 2022).
Specifically, this study provided a systematic and detailed overview of the meta-analysis study design to see the overall trend of investigation and generate a statistical synthesis of previous studies related to inquiry-based learning approach in science and the aforementioned 21st century skills.

Literature Search

A comprehensive literature search was conducted across seven electronic databases such as CORE, ProQuest, ERIC, Google Scholar, IOPscience, BASE, and DOAJ. The search was performed between February and March 2023. To improve retrieval accuracy, structured search strings were used, including: ("inquiry-based learning" OR "inquiry learning") AND ("critical thinking" OR "creative thinking"). These terms were applied primarily to titles, abstracts, and keywords, depending on the search functionalities of each database.

The intensive literature search covered the period of 2013 to 2023. This period was chosen to cover exactly ten (10) years of current research studies on IBLA. Only studies written in English were included. Both peer-reviewed journal articles and grey literature, such as theses and dissertations, were considered to minimize publication bias. Initial search results yielded 258,960 hits that include 226,521 journal articles and 32,439 theses and dissertations for both critical thinking and creative thinking skills.

However, not all retrieved theses and dissertations were fully screened due to accessibility limitations and relevance filtering. After applying the publication year restriction, removing duplicates, and conducting preliminary screening based on titles, abstracts, and keywords, a total of 4,420 studies remained for further evaluation. Among the theses and dissertations identified, only those with accessible full texts and sufficient methodological details were included in the screening process and subjected to the inclusion and exclusion criteria in subsequent screening stages.

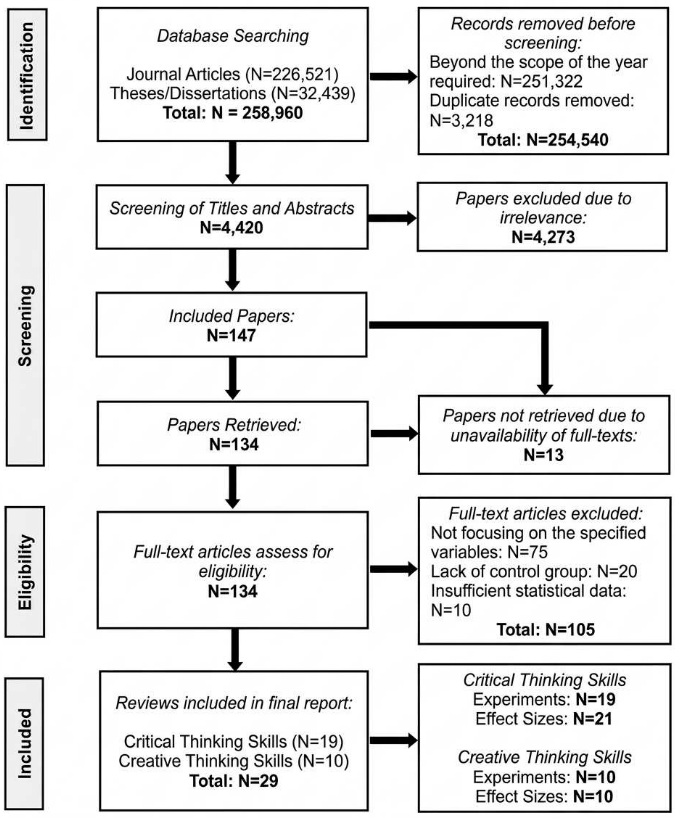


Figure 1. PRISMA Flowchart of the Study Selection Process

Figure 1 presents the PRISMA flowchart of the study selection process. During the identification stage, a total of 251,322 records were removed beyond the scope of the covered period, and a total of 3,218 records were excluded as duplicates. A total of 4,420 studies remained for screening. During the screening stage, titles, abstracts, and keywords were reviewed, resulting in the exclusion of 4,273 studies due to irrelevance to inquiry-based learning, critical thinking skills, or creative thinking skills. This yielded 147 included studies for the document retrieval stage, of which 134 were retrieved, and 13 papers were not retrieved due to the unavailability of full-texts.

In the eligibility stage, full-text articles were assessed. Of the remaining 134 studies, 105 were excluded for not meeting the inclusion criteria. A total of 75 studies did not focus on the specified variables, 20 studies were lack of control group, and 10 studies had insufficient statistical data. Finally, 29 studies were included in the meta-analysis, comprising 19 studies on critical thinking skills and 10 studies on creative thinking skills.

Eligibility Criteria

The study had adapted the criteria that were utilized in the meta-analysis studies of Aquino et al. (2025) and Camarao and Monterola (2021). To be eligible for inclusion in the current meta-analysis, the articles, theses, and dissertations (a) had to focus on the inquiry-based learning approach. Studies were automatically excluded if they did not aim to enhance learning outcomes. Only studies that (b) dealt with the dependent variables 'critical thinking skills' and 'creative thinking skills' were included. The meta-analysis focused explicitly on these learning outcomes and did not include other types of available measures. In terms of the subject domain, the study just (c) limited its coverage to science as it aimed to analyze the effects of IBLA on the said learning outcomes. Moreover, the research (d) had to compare students under the experimental group that received a particular inquiry-based learning approach against students under the control group that was exposed to a conventional teaching approach (CTA). In this study, CTA refers to teacher-centered instructional methods commonly described in the literature, such as lecture-based instruction, direct instruction, textbook-based learning, or traditional laboratory activities with predetermined procedures.

To ensure consistency, studies were included only if the control condition was explicitly described as non-inquiry-based or followed structured, teacher-directed methods without active student inquiry. Descriptions of control group instruction were extracted from each study and reviewed to verify alignment with this definition. However, variations in the implementation of CTA across studies were noted and considered during interpretation. The research sample (e) had to consist of primary, secondary, or tertiary school students with at least ten students per group to ensure that the effect size of Cohen's d would be approximately normally distributed (Hedges & Olkin, 1985; de Boer et al., 2018). Finally, the research (f) had to provide pretest and posttest and/or delayed test measures that are expressed in means and standard deviations, means and standard errors, t-test, or F-test.

Coding Studies

The researchers coded all the studies that were eligible for analysis. The data extracted from studies followed the eligibility criteria, and coding sheets were prepared to delineate each study feature based on the data extracted. Careful consideration was given to qualified studies as these served as the framework for analysis. Each column of the matrix was coded according to the author's publication date, publication type, educational level, and domain in science. The following studies were included in the meta-analysis under critical thinking skills.

Table 1. Studies Included in Meta-analysis Under Critical Thinking Skills

Author(s)	Publication Type	Educational Level	Domain in Science
Aidoo et al. (2022)	Journal Article	Junior Level	Chemistry
Alkan (2018)	Journal Article	College Level	Analytical Chemistry
Atkinson (2016)	Dissertation	Junior Level	Biology
Azzam (2020)	Dissertation	Junior Level	Physics
Cornejo et al. (2022)	Journal Article	College Level	Natural Science

Egbutu & Okeke (2021)	Journal Article	Senior Level	Chemistry
Elisanti et al. (2018)	Journal Article	Senior Level	Natural Science
Farah & Ayoubi (2020)	Journal Article	Junior Level	Chemistry
Mitarlis et al. (2020)	Journal Article	College Level	Organic Chemistry
Nafingah et al. (2020)	Journal Article	Junior Level	Physics
Pahrudin et al. (2021)	Journal Article	Junior Level	Physics
Pakpahan et al. (2019)	Journal Article	Senior Level	Physics
Perdana et al. (2020)	Journal Article	Senior Level	Science
Qamariyah et al. (2021)	Journal Article	College Level	Chemistry
Styawan & Arty (2021)	Journal Article	Senior Level	Thermochemistry
Susilowati et al. (2018)	Journal Article	Senior Level	Biology
Syahrial et al. (2019)	Journal Article	College Level	Science
Wardani & Djukri (2020)	Journal Article	Senior Level	Biology
Zain & Jumadi (2018)	Journal Article	Senior Level	Physics

Among the 19 studies included under critical thinking skills, two studies, such as Atkinson (2016) and Egbutu & Okeke (2021), contributed two effect sizes each due to the presence of multiple independent comparisons within the same study.

On the other hand, the following studies were included in the meta-analysis under creative thinking skills.

Table 2. Studies Included in Meta-analysis Under Creative Thinking Skills

Author(s)	Publication Type	Educational Level	Domain in Science
Algiani et al. (2023)	Journal Article	Senior Level	Biology
Dewi et al. (2021)	Journal Article	Senior Level	Physics
Hasan et al. (2019)	Journal Article	Senior Level	Biology
Hasancebi et al. (2021)	Journal Article	Junior Level	Science
Juniar et al. (2021)	Journal Article	College Level	Analytical Chemistry
Kirici & Bakirci (2021)	Journal Article	Junior Level	Science
Mitarlis et al. (2020)	Journal Article	College Level	Organic Chemistry

Nurfitria & Hertanti (2020)	Journal Article	Junior Level	Physics
Perdana et al. (2020)	Journal Article	Senior Level	Science
Suardana et al. (2019)	Journal Article	Junior Level	Science

Some studies, such as Mitarlis et al. (2020) and Perdana et al. (2020), contributed data to both critical thinking and creative thinking analyses because they reported multiple outcome variables. These were treated as separate effect sizes under each domain.

Data Analysis

To carry out the meta-analysis, the researcher utilized the Meta-Essentials Tools (MET) software version 1.4 created by Suurmond, van Rhee, and Hak (2015). This tool was applied to calculate effect sizes, specifically Cohen's d and Hedges' g, along with the variances of each intervention using statistical data from the 29 included studies. Standard mean differences were then derived from posttest results on students' critical and creative thinking skills, based on reported means and standard deviations or standard errors. When descriptive statistics such as means and standard deviations were not reported, effect sizes were computed from inferential statistics (e.g., t-test and F-test values) using standard conversion procedures. Specifically, effect sizes were derived following established formulas outlined in Introduction to Meta-Analysis, which allow transformation of test statistics into standardized mean differences (Cohen's d). These methods assume that the reported statistics are based on comparisons between independent groups and that the underlying distributions are approximately normal. Several studies required effect size conversion from t-test or F-test values due to incomplete reporting of descriptive statistics. These converted effect sizes were treated as comparable to those calculated directly from means and standard deviations, as recommended in meta-analytic practice.

MET was also used to examine possible publication bias and to conduct Rosenthal's (1979) fail-safe N analysis, which estimates how many unpublished studies with null results would be needed to eliminate the observed significant effect. The overall significance of the combined effect was further assessed using z-test statistics and corresponding p-values.

In cases where a single study reported multiple effect sizes, these were included separately only when they represented independent samples or comparisons. When effect sizes were derived from the same sample, extra caution was taken to avoid violating the independence assumption of meta-analysis. In addition to computing pooled effect sizes using the random-effects model, heterogeneity among studies was assessed using Cochran's Q, I^2 statistic, and T^2 to determine the extent of variability across studies.

To ensure robustness of the results, sensitivity analysis and potential moderator analyses are recommended for future research to examine the influence of study characteristics on the overall effect size. Publication bias was assessed using multiple approaches, including funnel plot visualization for asymmetry to detect potential bias and Rosenthal's fail-safe N.

The abovementioned studies of Mitarlis et al. (2020) and Perdana et al. (2020) were included in both the critical thinking and creative thinking skills datasets because they reported outcomes for both variables. These effect sizes were treated as separate entries because they correspond to different outcome measures. However, since these outcomes may have been derived from the same sample of participants, the assumption of independence may be partially violated. Given the use of MET, which does not support multivariate meta-analysis, the effect sizes were analyzed separately by outcome domain. This approach minimizes direct dependence within each analysis, although some degree of correlation between outcomes cannot be entirely ruled out.

RESULTS

Posttest effects of inquiry-based learning approach on critical thinking skills

Posttest measures of critical thinking skills were obtained from 19 studies, yielding a total of 21 effect sizes. Two of the included studies contributed more than one effect size because they reported results for multiple independent experimental comparisons. These studies were treated as providing separate effect sizes in the analysis. The summary statistics shown in Table 3 indicate that the overall effect size (d = 1.59) indicates a very large to huge effect, exceeding the conventional threshold for a 'large' effect (d = 0.80) proposed by Cohen (1988).

In practical terms, this suggests a substantial improvement in students' critical thinking skills under the inquiry-based learning approach. To enhance interpretability, the effect size was translated into a percentile gain. An effect size of d = 1.59 corresponds approximately to a percentile gain from the 50th percentile (control group) to about the 94th percentile (experimental group). This implies that the average student exposed to IBLA outperformed approximately 94% of students in the conventional teaching group. This means that there was a significant overall effect of the inquiry-based learning approach on the critical thinking skills of students in science compared to students under the conventional teaching approach, as supported by the z-test and p-values. Moreover, Rosenthal's fail-safe N shows that an additional 4,615 null-effect studies would be needed to bring the p-value beyond the .05 level of significance.

Table 3. Posttest Mean Effect Size for Critical Thinking Skills (n = 1,639)

	k	*d*	SE	95% CI	*z*-value	*p-value*
Overall	19	1.59	0.25	[1.08, 2.11]	6.47	0.000

**p < .05, fail-safe N = 4,615*

The combined effect size was also supported by the Weights and Forest Plot-Random Effects Model, which visualized the individual differences in the results of each study and displayed a graphical presentation summarizing all relevant studies for meta-analysis.

The weights of each article under critical thinking skills are shown in Figure 2 below. The weight given to each study was chosen to be the inverse of the variance of the effect estimate (Shaneyfelt, 2013). Therefore, studies with greater weights had smaller 95% confidence intervals (see Study 2) while studies with smaller weights had larger 95% confidence intervals (see Study 12). This choice of weight minimized the uncertainty of the pooled effect estimate.

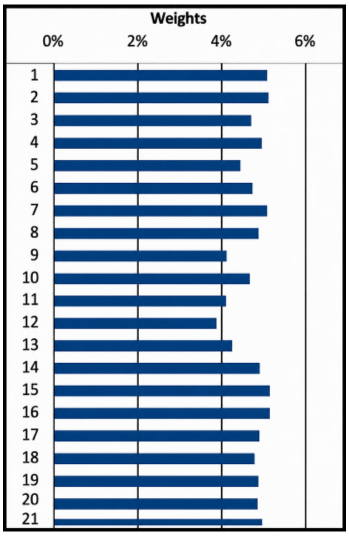


Figure 2. Weights of Each Article Under Critical Thinking Skills

The forest plot showing the effect sizes distribution of 19 studies is also presented in Figure 3. The effect size distribution of 19 studies showed that the confidence intervals of studies 1 and study 2 touched the line of no effect. Thus, studies 1 and 2 had lower values of Hedges' g and higher values of weights that indicated a shorter line of 95% confidence intervals. This implied that as the 95% confidence intervals of studies 1 and 2 overlapped the line of no effect, the results of both studies were not significant. Hence, the p-value is greater than 0.05 (Lee et al., 2020). The two (2) studies by Atkinson (2016) did not observe a statistical difference between the control group and the experimental group. The inquiry-based learning approach had no effect on the student's critical thinking skills for those studies only.

On the other hand, study 16 shows the highest weight of 5.17% which indicated the highest influence and made a big difference in the pooled results. The narrower the confidence interval, the higher the percentage weight, and most significantly, the more influence that study has on the pooled results. It was shown in the figure below that study 16 did not surpass the line of no effect value of 0 in the 95% confidence interval, the results were significant and the same goes with other eligible studies.

In the case of study 12 with the highest effect size Hedges' g of 5.04 but with the lowest weight of 3.91% indicating the highest values of 95% confidence interval, it was observed that there is a statistically significant difference between the control (3.0912) and experimental (2.2033) groups which still indicated a good influence on the pooled results with sample size 32 for both groups.

Thus, based on the forest plot showing the effect sizes' distribution of 19 studies, there was a statistically significant difference between the groups with a p-value less than the 0.05 threshold of significance. This indicates that the inquiry-based learning approach improved the critical thinking skills of students better than the conventional teaching approach.

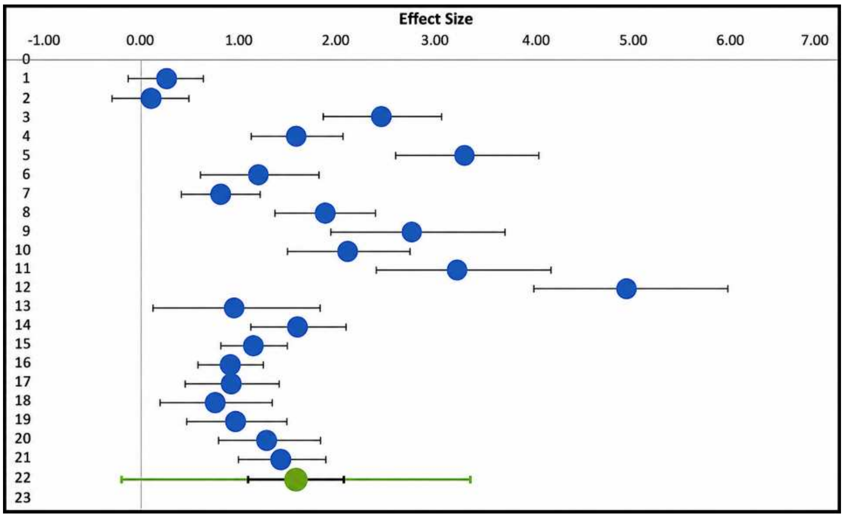


Figure 3. Forest Plot Showing the Effect Sizes' Distribution of 19 Studies

Evaluation of Heterogeneity Between Studies

The heterogeneity analysis revealed considerable variation among the included studies. This meta-analysis followed the interpretation guidelines of Higgins and Thomas (2003), where I^2 values of 25%–50% indicate low heterogeneity, 50%–75% indicate moderate heterogeneity, and 75%–100% indicate high heterogeneity. Based on this classification, the I^2 value of 91.14% reflects a very high level of heterogeneity, indicating that most of the variability in effect sizes is due to true differences across studies rather than sampling error or random chance.

This finding is further supported by Cochran's Q test ($Q = 225.61$, $p < 0.05$), which shows that the differences among the included studies are statistically significant and not due to random variation alone. Moreover, the T^2

value of 0.68 represents a substantial level of between-study variance, reinforcing the presence of real differences in effect sizes.

Taken together, these results suggest that although inquiry-based learning generally yields a large positive effect, the magnitude of its impact is not consistent across all contexts. The variability may be attributed to differences in educational settings, learner populations, duration and intensity of implementation, teacher facilitation strategies, and subject-specific content. This implies that while the overall intervention is effective, its outcomes are likely influenced by contextual and methodological factors, highlighting the importance of considering study conditions when interpreting the pooled effect size.

Table 4. Heterogeneity Test Under Critical Thinking Skills

	Q	p_Q	I^2	T^2	T
Overall	225.61	0.000	91.14%	0.68	0.83

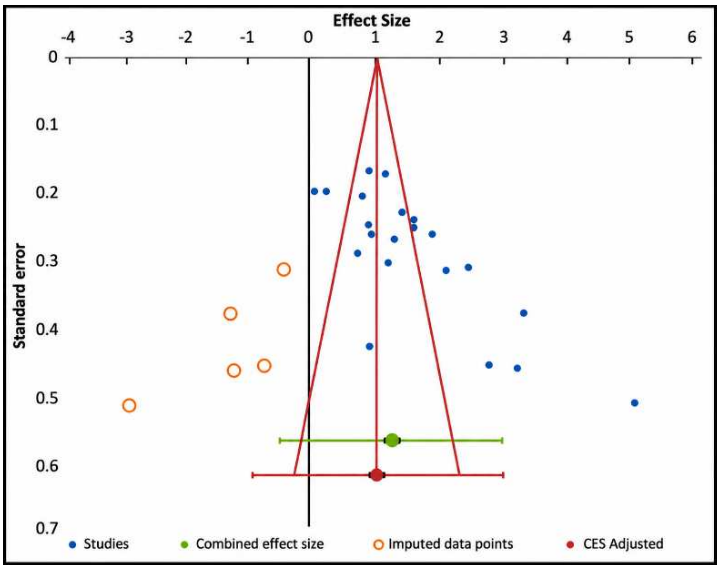
$*p < 0.05$

Analysis of the Publication Bias of the Studies

This analysis was conducted to determine possible bias that may arise after the completion of the studies. It is generally assumed that studies with statistically significant results are more likely to be reported and published compared to those with non-significant findings. Because of this tendency, the overall effect size may be inflated beyond the true effect. Publication bias is used to detect and correct this type of distortion in the combined effect size estimates. The funnel plot shows an asymmetrical distribution of effect sizes, suggesting that some studies may be missing. To address this, the trim-and-fill method was applied to estimate and adjust for the potentially absent studies, thereby providing a corrected overall effect size (Hak et al., 2016).

The funnel plot for critical thinking skills reveals a noticeable asymmetry, which may indicate the presence of publication bias or small-study effects. In particular, the distribution appears to lack studies on the left side, suggesting that research reporting smaller or negative effects may be underrepresented in the analysis. This observation is further supported by the trim-and-fill procedure, which estimates the number of potentially missing studies required to restore symmetry in the funnel plot. After imputing these studies, the recalculated pooled effect size is reduced compared to the original estimate (d = 1.59), indicating that the initial effect may have been somewhat overestimated.

Despite this adjustment, the overall effect remains positive and statistically significant, reinforcing the conclusion that the inquiry-based learning approach (IBLA) has a beneficial impact on students' critical thinking skills. However, the presence of asymmetry and the reduction in effect size following correction highlight the importance



of interpreting the findings with caution. These results suggest that while IBLA is effective, the magnitude of its impact may be more moderate than initially indicated. Consequently, future studies employing rigorous experimental designs and efforts to reduce reporting bias are necessary to obtain a more accurate estimate of the true effect.

Figure 4. Funnel Plot of Studies' Effect Sizes Under Critical Thinking Skills

Posttest effects of inquiry-based learning approach on creative thinking skills

A total of 10 interventions and 10 effect sizes from 10 studies with posttest measures were used to measure the effects of the inquiry-based learning approach on students' creative thinking skills in science. The combined effect size in Table 4 shows that the d statistic (2.02) indicates a very large to huge effect (d = 2.02), far exceeding conventional benchmarks for educational interventions. In terms of practical interpretation, an effect size of d = 2.02 corresponds approximately to a percentile gain up to about the 98th percentile. This suggests that students exposed to the inquiry-based learning approach performed better than approximately 98% of those in the control group. As suggested by the statistical z-test and p-values, the learners who received the IBLA outperformed the learners who received the CTA. Rosenthal's fail-safe N has also estimated that 1,342 unpublished studies with zero mean effect would be required to make the obtained overall effect statistically nonsignificant.

Table 5. Posttest Mean Effect Size for Creative Thinking Skills (n = 614)

	k	*d*	SE	95% CI	*z*-value	*p-value*
Overall	10	2.02	0.36	[1.20, 2.85]	5.58	0.000

**p < .05, fail-safe N = 1,342*

Moreover, Figure 5 below shows the weights of each article under creative thinking skills. It reported greater weights compared to that of the critical thinking skills which indicate that studies under creative thinking skills had smaller 95% confidence intervals.

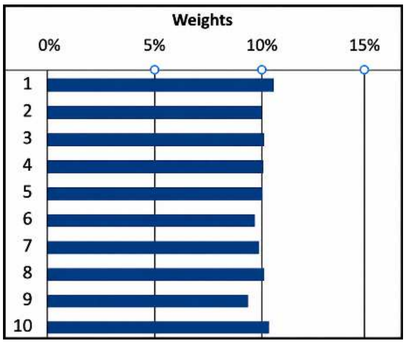


Figure 5. Weights of Each Article Under Creative Thinking Skills

The forest plot in Figure 6 also presents the effect size distribution of the 10 eligible studies. It showed that there are no studies that crossed the line of no effect. This implied that as the 95% confidence intervals of all the individual studies did not overlap the line of no effect, then the results of all the studies were significant. Hence, the p-value is less than the 0.05 level of significance (Lee et al., 2020). All studies showed that there is a statistically significant difference between the control group and the experimental group. Therefore, inquiry-based learning has an effect on the students' creative thinking skills across all the studies. It is also evident based on the given data about the properties of population parameters.

For instance, study 9 with the highest effect size (Hedges' g) of 4.50 but with the lowest weight of 9.39%, indicating the highest values of 95% confidence intervals reported a statistically significant mean difference

between the control group (18.08) and experimental group (31.11), which indicated a good influence on the pooled results with a sample size of 26 and 56, respectively.
The combined effect size (green dot) of the 10 studies showed that there was a statistically significant difference between the groups with a p-value less than the 0.05 threshold of significance. Thus, the students under the IBLA outperformed the students under the CTA in terms of creative thinking skills.

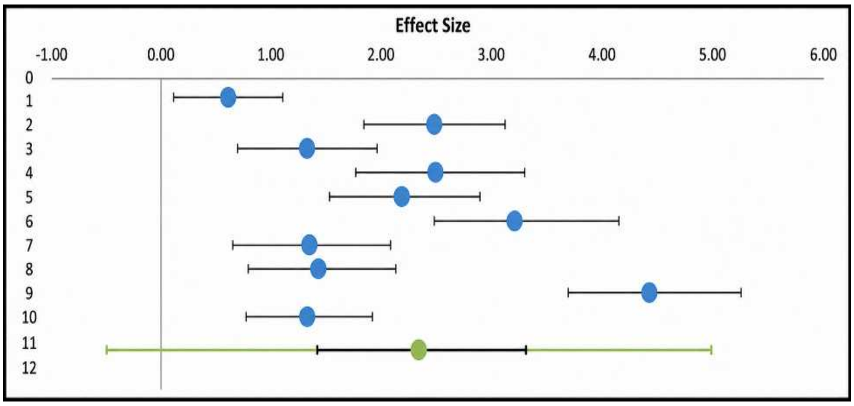


Figure 6. Forest Plot Showing the Effect Sizes' Distribution of 10 Studies

Evaluation of Heterogeneity Between Studies

The combined effect size presented in Table 5 (d = 2.02) reflects an extremely large overall effect of the intervention. However, the heterogeneity analysis indicates that the effect sizes are not fully consistent across the included studies. The I^2 value of 91.11% suggests a very high level of heterogeneity, meaning that most of the variation in effect sizes is due to real differences among studies rather than random error. This is further supported by Cochran's Q statistic ($Q = 101.18$, $p < 0.05$), which confirms that the observed variability is statistically significant and exceeds what would be expected by chance. In addition, the T^2 value (1.01) indicates a substantial amount of between-study variance.

These results imply that although inquiry-based learning generally has a strong positive impact on students' creative thinking skills, the magnitude of its effectiveness is not uniform across all studies. The differences may be attributed to variations in instructional design, duration of intervention, learner characteristics, subject matter, and classroom implementation fidelity. This suggests that contextual factors play an important role in influencing how effectively inquiry-based learning enhances creative thinking, and therefore, the pooled effect size should be interpreted with consideration of these moderating variables.

Table 6. Heterogeneity Test Under Creative Thinking Skills

	Q	p_Q	I^2	T^2	T
Overall	101.18	0.000	91.11%	1.01	1.01

$^*p < 0.05$

Analysis of the Publication Bias of the Studies

The funnel plot for creative thinking skills suggests the presence of potential publication bias or small-study effects, as indicated by the asymmetrical distribution of effect sizes and the relative absence of studies on the left side of the plot. This pattern implies that studies reporting smaller or non-significant effects may be underrepresented in the dataset. To further examine this issue, a trim-and-fill analysis was conducted, which estimated the number of potentially missing studies and adjusted the overall effect size accordingly. The results of this procedure indicate that the adjusted effect size is lower than the initially observed value (d = 2.02), although the direction of the effect remains positive.

These findings suggest that while the inquiry-based learning approach (IBLA) continues to demonstrate a beneficial impact on creative thinking skills, the magnitude of the effect may be overestimated due to selective reporting or other forms of bias. Moreover, given the relatively small number of included studies, the stability of the estimated effect size may be sensitive to the influence of individual studies with large effects. Therefore, the results should be interpreted with caution, and future research incorporating a larger body of evidence and more rigorous study designs is recommended to provide a more precise and unbiased estimate of the true effect.

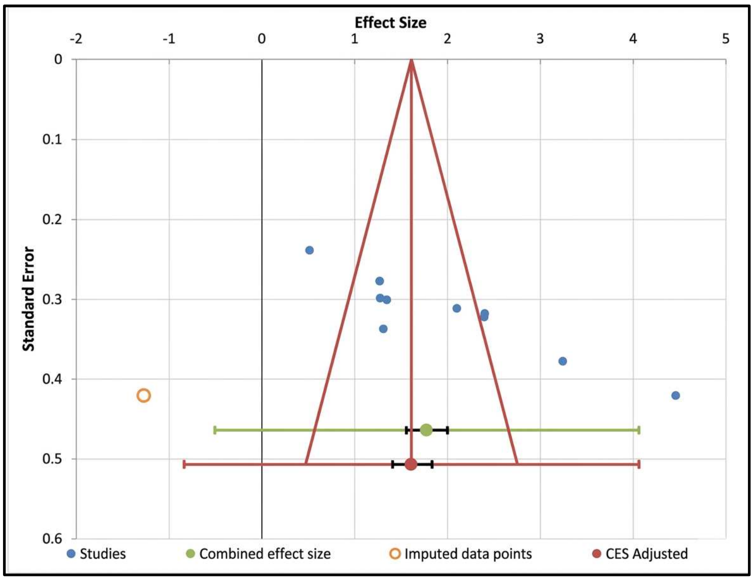


Figure 7. Funnel Plot of Studies' Effect Sizes Under Creative Thinking Skills

Discussion

This meta-analysis provides evidence that inquiry-based learning has a strong positive effect on students' critical and creative thinking skills. Learners exposed to this approach consistently demonstrate higher levels of higher-order thinking compared with those taught through conventional, teacher-centered methods. In particular, guided forms of inquiry have been linked to significant improvements in both critical thinking (Purwasi, 2020) and creative thinking (Allan, 2017), suggesting that structured inquiry activities can effectively support cognitive development in science education. In addition to enhancing thinking skills, inquiry-based learning promotes active participation, collaboration, and deeper engagement with content, making it a valuable approach for diverse classroom settings (Indarasati et al., 2019).

Despite these promising findings, the effect sizes obtained in this study (d = 1.59 for critical thinking and d = 2.02 for creative thinking) are considerably larger than those typically reported in educational research, where effect sizes commonly range from 0.20 to 0.80. This discrepancy calls for cautious interpretation. Several factors may explain the unusually large estimates. First, small sample sizes in the primary studies may have contributed to inflated effect sizes. Second, publication bias may have favored studies reporting statistically significant and larger effects, even though the fail-safe N suggests a degree of robustness. Third, methodological limitations—such as non-randomized designs, lack of blinding, teacher-related influences, and the use of nonequivalent comparison groups—may have led to overestimation of the true effect.

Additional considerations further qualify the findings. The meta-analysis for creative thinking was based on a relatively small number of studies, making the results more sensitive to extreme values and limiting the stability of the estimates. Moreover, variations in how the conventional teaching approach (CTA) was defined and implemented across studies may have influenced the observed differences. Although CTA was generally described as teacher-centered instruction (e.g., lectures or direct teaching), differences in instructional practices across contexts could have affected the magnitude of the reported effects.

Methodological limitations also need to be acknowledged. Some studies contributed multiple effect sizes derived from the same sample, raising the possibility of dependent data that are not fully accounted for in standard meta-analytic models. In addition, the absence of a formal risk-of-bias assessment limits the ability to evaluate the overall quality of the included studies. Future research may address these concerns by applying multivariate meta-analysis or robust variance estimation techniques, as well as incorporating standardized tools to assess study quality.

To strengthen the validity of the findings, further analyses are recommended. Sensitivity analyses, such as excluding studies with extreme effect sizes, can help determine whether the results are driven by a small number of influential studies. Subgroup or moderator analyses based on variables such as educational level, subject area, or type of inquiry-based approach may also explain the variability in effect sizes across studies.

Overall, the results suggest that inquiry-based learning has strong potential to enhance students' higher-order thinking skills. The reported effect sizes imply substantial gains in performance; however, such outcomes depend on effective implementation. Factors such as instructional design, teacher preparation, classroom environment, and student readiness play a critical role in determining the success of this approach. Therefore, while inquiry-based learning appears to be highly beneficial, the magnitude of its impact is likely context-dependent and should not be assumed to be uniform across all educational settings.

CONCLUSION

Learning science through an inquiry-based learning approach (IBLA) appears to have a substantial positive effect on students' critical thinking and creative thinking skills. The large effect sizes observed in this meta-analysis suggest that IBLA has strong potential to enhance these learning outcomes compared to conventional teaching approaches.

However, these findings should be interpreted with caution. The magnitude of the effect sizes may be influenced by factors such as publication bias, small sample sizes, lack of blinding, and teacher expectancy effects commonly present in quasi-experimental studies. In addition, variability in study design and implementation across the included studies may contribute to the observed results.

Therefore, while IBLA shows considerable promise as an instructional approach in science education, further high-quality research employing rigorous experimental designs and standardized methodologies is needed to confirm the consistency and generalizability of its effects

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