Inquiry-Based Learning and Critical Thinking Skills of Higher Education Students in the Era of Revolution 5.0: A Meta-analysis

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Abstract:

There are many studies on the inquiry-based learning model on the critical thinking ability of students in universities in Indonesia. However, there has been no in-depth and accurate conclusion of inquiry-based learning and critical development of students. This study aims to determine the influence of inquiry-based learning and the development of students' critical thinking in STEM learning. In this study, 20 studies obtained from google scholar were analyzed; ERIC; ScienceDirect, Wiley, Taylor of Francis, and Emerald from 2021 to 2024 with a total of 1305 participants. The data analysis in this study was done with JSAP 0.16.3 software assistance. The effect size criteria in the study were determined with a confidence interval of 95%. The results of this study concluded that the effect size value was obtained through a random effect model, which was 1.049 (strong effect size). These findings show that the application of the inquiry-based learning model has a significant influence on the development of students' critical thinking in STEM learning. Inquiry-based learning is very effectively applied to students to improve the critical thinking of university students in the era of the 5.0 revolution.

Key words : Inquiry Based Learning; Critical Thinking; Revolution 5.0; Meta-analysis

1. Introduction:

The Industrial Revolution 5.0 marks a significant change in the industrial world that prioritizes the integration of advanced technology with humanitarian aspects. In this context, students are required to develop higher critical thinking skills to adapt to rapid and complex changes[1] ; [2]. Critical thinking skills enable students to analyze situations, identify problems, and formulate innovative solutions that can be applied in a variety of contexts. In addition, students must also be able to critically evaluate information, question assumptions, and make decisions based on data and evidence [3]; [4].

The main characteristics of the Industrial Revolution 5.0 are personalization and sustainability, which requires students to have a deep understanding of technology and how it can be applied effectively and ethically[5]; [6] . Students need to master skills in using technological tools such as artificial intelligence, robotics, and the Internet of Things (IoT), and integrate these technologies with human creativity and empathy. With strong critical thinking skills, students can create solutions that are not only effective but also socially and environmentally responsible, answering increasingly complex global challenges [7] ; [8].

Furthermore, the Industrial 5.0 revolution requires students to be able to collaborate effectively in multidisciplinary and cross-cultural teams [9]; [10]; [11] . Critical thinking skills will help students to contribute significantly to discussions and collaborative projects, with the ability to articulate ideas, evaluate peer contributions, and integrate diverse perspectives [12] ; [13] . Thus, the development of critical thinking skills is a key element in higher education which aims to prepare students to become leaders and innovators in the era of the Industrial Revolution 5.0, able to face challenges and take advantage of existing opportunities in a smart and ethical way.

Critical thinking skills are one of the important aspects that must be possessed by students in the era of Revolution 5.0 [14] ; [15]). In this context, the ability to critically analyze information, question assumptions, and evaluate different perspectives and sources of information is vital. These skills assist students not only in navigating an ever-growing and often complex sea of information, but also in making appropriate, evidence-based decisions in fast-paced and often ambiguous situations[16]; [17]. Students with critical thinking skills are able to provide innovative insights and solutions, utilizing interdisciplinary knowledge and creativity [18] ; [19] ; [20] . These skills also strengthen students' adaptability in the face of dynamic and often disruptive changes in the workplace, equipping them to become effective leaders and innovators of the future. Thus, higher education institutions must make great efforts in integrating critical thinking learning into the curriculum [21].

One of the main problems faced in the development of critical thinking skills in higher education is the curriculum that tends to be still conventional and does not challenge students enough to think deeply and analytically [22]. Many study programs still apply passive learning methods, where students receive more information than are invited to explore and challenge these ideas. As a result, students are often unfamiliar with the process of asking critical questions, delving deeper into various arguments, or developing their own thinking based on strong analysis.

In addition, the lack of facilities and resources to support the critical thinking learning process is also an obstacle. There is a shortage of lecturers trained in teaching with techniques that promote active and critical engagement from students [23]; [24] . Also, inadequate libraries or limited access to the latest digital resources that can help students conduct research and investigations independently. As a result, while students may have the potential to develop critical thinking skills, these limitations often hinder the full development of those essential skills in an academic context

[25]. Therefore, it is necessary to have a learning model that is able to encourage students' critical thinking skills, one of which is inquiry-based learning.

Inquiry-Based Learning (IBL) is an educational method that prioritizes the use of questions, exploration, and investigation to trigger deep learning [26] ; [27]. This method is based on the principle that knowledge must be discovered by students through their own active processes, not just imparted by the teacher. In IBL, students are faced with real problems or open-ended questions that require critical and creative thinking to find solutions [28]. This approach allows students to develop critical thinking abilities and problem-solving skills while deepening their understanding of the subject matter [29]; [30]. IBL not only improves knowledge retention but also prepares students to be able to apply what they learn in real-world situations.

The inquiry-based learning model requires teachers to take on the role of facilitators who guide the learning process without dominating. Teachers must be able to prepare an environment that supports exploration and provide relevant resources for students to conduct independent investigations[31]. In addition, teachers need to develop stimulating questions that can invite students to think deeply and relate new knowledge to previous experiences. This process not only challenges students to become more active learners, but it also teaches them to appreciate the learning process itself as a path to a richer and more integrated understanding [32].

Previous research has identified a significant relationship between inquiry-based learning (IBL) and the improvement of critical thinking skills of university students in the era of Revolution 5.0. A study conducted by Thompson and Phillips (2020) shows that the application of IBL in the curriculum can improve students' analytical and evaluative abilities in dealing with complex and fast-paced situations. They found that students who engaged in inquiry-based learning tended to develop better critical thinking skills, including the ability to identify, analyze, and solve problems more effectively[8]. This research confirms that IBL facilitates more active and participatory learning, which is vital in preparing students for future challenges [33] ; [34] .

Furthermore, research by Lee and Liu (2021) expands the understanding of the effectiveness of IBL in a multidisciplinary context in higher education. They examine how students from different disciplines such as science, technology, and humanities can use IBL to improve their cross-disciplinary understanding and critical thinking skills. The results of the study show that through IBL, students are able to connect theory with practice and apply knowledge in real scenarios better, which is a key competency in the era of Revolution 5.0. This research underscores the importance of a supportive learning environment and adequate resources to support the successful implementation of IBL at the university level. Therefore, this study aims to determine the influence of inquiry-based learning and the development of students' critical thinking in era revolution 5.0.

2. Research Methods

Research Design

This research is a type of quantitative research with a meta-analysis approach. Meta-analysis is a type of research that quantitatively analyzes primary research to reach a conclusion (Öztop, 2023; Ulum, 2022). This meta-analysis serves to determine the influence of Inquiry Based Learning on students' critical thinking skills in universities in the era of the industrial revolution 5.0.

Eligibility Criteria

To obtain valid and relevant research data, it must meet the inclusion criteria consisting of 1) research must come from national and international journals indexed by SINTA, Scopus and Web of Science, 2) Research published in the period 2021-2024, 3) The research topic must be relevant, 5) The research sample > 30 participants and 6) The research data must report complete data to calculate the effect size value. Furthermore, the keywords for data search are "Inquiry based Learning", "Critical Thinking" and the Influence of Inquiry Based Learning on Students' Critical Thinking Skills". From the results of the search for data sources, 22 studies were obtained that met the criteria that can be seen in Table 2.

Data Analysis

In the meta-analysis research, the data analysis consisted of: 1) determining the effect size of each study; 2) Heterogeneity test and 3) calculation of the combined effect size [34]. Statistical analysis in the study with the help of JSAP 0.8.5 application. Furthermore, the effect size criterion is guided by Cohen's [35] can be seen in Table 1.

Table 1. Classification Effect Size

Value	**Classification**
0.0-0.20	Weak Effect
0.21-0.50	Modest Effect
0.51-1.00	Medium Effect
> 1.00	Strong Effect

3. Result and Discussion

Based on the results of searching for data sources through the database, 22 publications were obtained that met the inclusion criteria. Furthermore, the effect size and standard error can be seen in Table 2.

Table 2. Effect Size and Standar Error

No	Publication Code	Years	Effect Size	Standar Error
1	AP1	2022	2.09	0.34
2	AP2	2024	1.19	0.52
3	AP3	2024	0.92	0.33
4	AP4	2024	0.77	0.28
5	AP5	2022	1.24	0.41
6	AP6	2023	1.02	0.38

7	AP7	2024	1.17	0.44
8	AP8	2023	0.99	0.31
9	AP9	2023	2.41	0.51
10	AP10	2024	1.07	0.55
11	AP11	2021	0.72	0.29
12	AP12	2023	0.88	0.30
13	AP13	2024	0.91	0.22
14	AP14	2024	1.10	0.34
15	AP15	2024	2.06	0.51
16	AP16	2024	0.85	0.18
17	AP17	2024	1.22	0.57
18	AP18	2024	1.40	0.40
19	AP19	2023	0.95	0.36
20	AP20	2023	0.66	0.20
21	AP21	2024	0.81	0.28
22	AP22	2024	1.52	0.39

Table 2, the results of the analysis of 22 research publications showed that the effect size value ranged from 0.66 to 2.41. According to Cohen's effect size criteria in. There were twelve studies (n =12) with strong effect size values and research vessels (n =10) with medium effect size values. The next step is to determine the model used to analyze the 22 publications through the fixed and random effect models seen in Table 3.

Table 3. Fixed and Random Effect Model

	Q	df	p
Omnibus test of Coefficients Model	56.170	1	< 0.01
Test of Residual Heterogeneity	146.170	21	< 0.01

Based on Table 3, the Q value of 146,170 is greater than 56,170 with a confidence level of 95%, so the effect size variant is heterogeneously distributed. Therefore, the model used is a random effect model to calculate the average effect size of 22 publications. The next step is to check the publication bias of the 22 publications analyzed. Publication bias checks function to find out the problem of publication bias against the data used [36]. To determine the bias of publication in this study by funnel plot analysis and Rosenthal Fail Safe N test [37]; [38]; [39]; [40]; [41]. The results of the analysis of 22 publications with funnel plots can be seen in figure 1.

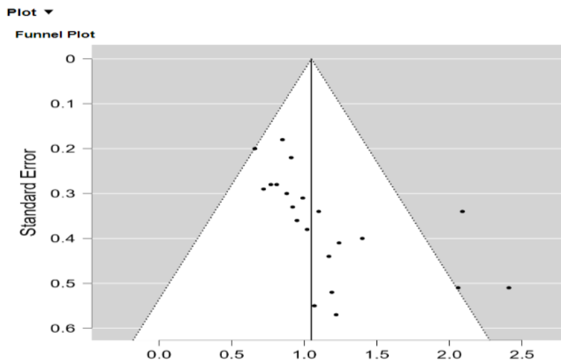

Figure 1. Funnel Plot Standar Error Random Effect

Figure 1, the results of the analysis of 22 publications It is difficult to know whether the funnel shape of the plot is symmetrical or asymmetrical, so it is necessary to carry out further tests, namely the Rosenthal Fail Safe N test.

Table 4. Rosenthal Fail Safe N Test

File Drawer Analysis			
	Fail Safe N	Target Significance	Observed Significance
Rosenthal	1700.00	0.050	< .001

Table 4, FSN value > 5k + 10 = 120, while the Fail Safe N value is 1700 with a significance level of 0.050 and p < 0.001, so in this meta-analysis there is no publication bias and the data can be scientifically accountable. The next step is to analyze the mean effect size values of 22 publications which can be seen in Table 5.

Table 5. Summary/ Mean Effect Size

Coefficient				
	Effect Size (d)	Standar Error	z	p
Intercept	1.049	0.314	12.090	< .001

Based on Table 5, the results of the analysis of 22 publications obtained a confidence level of 95% with a ceiling limit of 0.879 and an upper limit of 1,220. The result of the mean effect size is 1,049, the effect value is included in the strong category. Furthermore, the results of statistical analysis obtained a value of z = 12,090 and p <. 001, then the application of the inquiry-based learning model has a significant effect on the critical thinking skills of students in higher education compared to the conventional model in the 5.0 revolution era.

This research is in line with [42] that the Inquiry based learning model can improve students' critical and collaborative thinking skills in the student learning process. These findings are in accordance with [43] that the Inquiry based learning model can improve students' critical and collaborative thinking skills in the student learning process. Inquiry-Based Learning (IBL) is a powerful pedagogical approach that nurtures the cultivation of critical thinking skills, particularly crucial in the era of Revolution 5.0, where automation and digital technologies are at the forefront [44]; [45].

IBL encourages students to engage with learning materials actively and directly, formulating questions, conducting investigations, and deriving conclusions through a learner-centered approach. This method fosters a deeper understanding of subject matter, as it moves away from rote memorization to a more dynamic and investigative process. In higher education, where critical thinking is paramount, IBL helps students not only absorb knowledge but also apply it in innovative and practical ways, a key requirement in today's rapidly evolving job market [46]. The adoption of IBL in the context of Revolution 5.0 leverages the integration of advanced technologies like AI, big data, and IoT, which can significantly enhance the learning experience. For instance, data-driven insights can help customize student inquiries, making them more aligned with real-world problems[47]. This alignment not only increases engagement but also enhances students' abilities to think critically and solve complex challenges. Moreover, by utilizing these technologies, educators can provide immediate feedback, another critical component that supports the iterative nature of critical thinking [48]; [49].

Critical thinking, a cornerstone of higher education outcomes, is increasingly necessary for students to navigate the complexities of the modern world. Through IBL, students learn to question assumptions, view problems from multiple perspectives, and develop strong analytical skills[50]. These skills are essential for success in a knowledge-based economy where individuals are expected to be problem solvers and innovators. Additionally, the collaborative aspect of IBL mirrors the team-oriented and interdisciplinary work environments prevalent in many sectors today, preparing students for future professional settings [51]. Implementing IBL effectively requires significant shifts in teaching strategies and curriculum design. Educators must be adept at guiding rather than dictating the learning process and need to create an environment that encourages exploration and expression [52]; [53]. This might involve rethinking assessment methods to value creative solutions and process-oriented tasks over traditional testing. Furthermore, institutions must invest in training educators to use new technologies and pedagogical approaches effectively, ensuring that the benefits of IBL are fully realized.

4. Conclusion

From the results of this study, it can be concluded that the effect size value is obtained through a random effect model, which is 1,049 (strong effect size). These findings show that the application of the inquiry-based learning model has a significant influence on the development of students' critical thinking in STEM learning. Inquiry-based learning is very effectively applied to students to improve the critical thinking of university students in the era of the 5.0 revolution.

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