THE EFFECT OF MACHINE LEARNING-ASSISTED INQUIRY BASED LEARNING SIZE MODEL ON STUDENTS' PROBLEM-SOLVING THINKING SKILLS

Heppy Sapulete[1*], Tomi Apra Santosa[2], Hasyim Mahmud Wantu[3], Ahmad Zarnoto Zain[4], Aat Ruchiat Nugraha[5], Eko Nursalim[6], Tongam E Panggabean[7], Alex Irawan Triantho[8]

[1] Universitas Pattimura, Indonesia
[2,8] Akademi Teknik Adikarya, Indonesia
[3] IAIN Sultan Amai Gorontalo, Indonesia
[4] Universita PTIQ Jakarta, Indonesia
[5] Universitas Padjadjaran, Indonesia
[6] STAI Sangatta Timur, Indonesia
[7] Universitas PGRI Madiun, Indonesia
*Corresponding email:heppy.sapulete@gmail.com

Keywords

Inquiry Based Learning; Machine Learning; Problem-Solving Capabilities

Abstract

This study aims to determine the influence of the Machine Learning-assisted Inquiry Based Learning Model on Students' Problem-Solving Thinking Ability. This type of research is a quantitative research with a meta-analysis approach. The data sources in this study come from 12 reputable national and international journals published in 2022-2024. The data collection technique is direct observation through the jury database. The search for data sources in this study is based on google scholar; ERIC, Wiley and Sciencedirect. Data analysis is quantitative data analysis by calculating the effect size value. The results of the study concluded that the inquiry-based learning model assisted by machine learning had a positive influence on students' problem-solving ability with an effect size value of 1,02 in the high effects size category.

1. INTRODUCTION

The ability to think problem-solving has become one of the essential skills in 21st century education, along with the increasing complexity of global challenges that require creative and innovative solutions. In a rapidly evolving world, students need to have the ability to identify, analyze, and solve problems independently and collaboratively (Qamariyah et al., 2021; Ridwan et al., 2021). These abilities are not only relevant in an academic context but also in various aspects of life, including work, social interaction, and community participation (Asnur et al., 2024). Therefore, education must be designed to equip students with critical thinking skills, cognitive flexibility, and the ability to apply knowledge in new situations.

Challenges facing the modern world, such as climate change, technological developments, and global economic dynamics, require the younger generation to become tough problem solvers (Kim & Xin, 2022); (Zulyusri et al., 2023; Wantu et al., 2024). In the context of education, traditional approaches that focus on memorizing facts are no longer sufficient to prepare students for the dynamic world of work. In contrast, problem-based learning models, such as Inquiry-Based Learning (IBL), provide students with the opportunity to develop problem-solving thinking skills through exploration and investigation (Yustina et al., 2022). This process allows students to engage directly in active learning, build a deep understanding, and apply concepts to real-life situations (Deniş-Çeliker & Dere, 2022; Ernawati & Sari, 2022).

In addition, the integration of technologies, such as Machine Learning, can strengthen the development of these skills. Technology gives students access to relevant tools and data, and allows for more adaptive and personalized learning (Karaoglan-Yilmaz et al., 2023). Machine Learning can help students understand patterns and analyze complex data, which supports them in solving problems more effectively. By blending innovative technology and pedagogy, 21st century education not only builds problem-solving thinking skills but also prepares students to become adaptive and inovatif (Zulkifli et al., 2022; Ali et al., 2024; Nurtamam et al., 2023).

The ability to think problem-solving has become one of the essential skills in 21st century education, along with the increasing complexity of global challenges that require creative and innovative solutions. In a rapidly evolving world, students need to have the ability to identify, analyze, and solve problems independently and collaboratively (Angraeni & Yusuf, 2022; Boonsathirakul & Kerdsomboon, 2023). These abilities are not only relevant in an academic context but also in various aspects of life, including work, social interaction, and community participation. Therefore, education must be designed to equip students with critical thinking skills, cognitive flexibility, and the ability to apply knowledge in new situations (Antonio & Prudente, 2023; Anwar et al., 2023).

Challenges facing the modern world, such as climate change, technological developments, and global economic dynamics, require the younger generation to become tough problem solvers (Gök & Boncukçu, 2023). In the context of education, traditional approaches that focus on memorizing facts are no longer sufficient to prepare students for the dynamic world of work. In contrast, problem-based learning models, such as Inquiry-Based Learning (IBL), provide students with the opportunity to develop problem-solving thinking skills through exploration and investigation. This process allows students to engage directly in active learning, build a deep understanding, and apply concepts to real-life situations (Fathonah et al., 2023; Siew & Basari, 2024).

As technology evolves, the application of Machine Learning (ML) in education offers new opportunities to support the development of problem-solving thinking skills. Machine Learning can personalize students' learning experiences by providing data-driven analysis, adapting materials to individual needs, and realistic simulations to delve into complex problems (Widyaningtyas et al., 2024). The combination of ML with the IBL approach creates a dynamic learning environment, where students can access relevant data, identify patterns, and develop solutions based on the insights this technology generates. With this integration, education not only becomes more relevant to the needs of the 21st century but is also able to empower students to overcome future challenges more effectively(Lee & Lee, 2024). Therefore, it is necessary to have a learning model that can encourage students' problem-solving skills, namely inquiry-based learning.

Inquiry-Based Learning (IBL) is a learning approach that places students as active subjects in the learning process through exploration, investigation, and reflection on a problem or question(Kılıç & Sciences, 2022). This approach is particularly relevant in answering the

challenges of 21st century education because it encourages students to develop critical, creative, and analytical thinking skills. By giving students the freedom to seek information, propose hypotheses, and design solutions, IBL helps them build a deep understanding of the concepts being studied (Siew & Chai, 2024). This method also allows students to relate learning to real-world contexts, so they not only master the theory but are also able to apply it practically (Oktarina et al., 2021).

In addition, IBL supports effective collaboration and communication, as students often work in groups to share ideas and solve problems together(Fajri et al., 2023). This approach is aligned with the need for active learning that emphasizes the full involvement of students in the learning process. In this context, the role of the teacher is transformed into a facilitator who helps students direct their exploration and provide constructive feedback. With its high relevance in building 21st-century skills, IBL has become one of the effective learning methods to prepare students for future life and career challenges (Tessema et al., 2024; Dwi et al., 2024).

Although Inquiry-Based Learning (IBL) has proven effective in improving students' critical thinking and problem-solving skills, there is still a research gap regarding how technologies, particularly Machine Learning (ML), can be integrated to support this approach(Sonsun et al., 2023). Many previous studies have focused more on conventional IBL implementation, without leveraging the potential of advanced technologies such as ML to enrich students' learning experiences (Sreejun & Chatwattana, 2023). In fact, ML has the ability to personalize learning, analyze data in real-time, and provide adaptive feedback. This opens up opportunities to create a more effective and efficient learning approach in honing problem-solving thinking skills. Therefore, this study seeks to fill the gap by exploring the effects of ML integration in the IBL model on the development of students' thinking skills, especially in the context of solving complex problems

2. RESEARCH METHODS

This study uses a meta-analysis method to evaluate the effectiveness of the Inquiry-Based Learning (IBL) learning model supported by Machine Learning (ML) on students' problem-solving thinking skills. Meta-analysis is carried out by collecting and analyzing relevant previous research results from various journals, conferences, and academic databases. Inclusion criteria included studies that measured the effectiveness of ML-based IBL models, involved students at primary to higher education levels, and used a measure of problem-solving thinking ability as a dependent variable. Studies that did not meet these criteria or had insufficient data for statistical analysis were excluded from the study.

The collected data was analyzed using statistical software to calculate the effect size as an indicator of the extent to which ML increases the effectiveness of IBL in improving problem-solving thinking skills. Heterogeneity analysis was carried out to determine the level of variability of the research results, while the moderator test was used to explore factors that could affect the effectiveness of the model, such as the level of education, the type of problems faced by students, and the duration of the intervention. This study aims to provide a comprehensive overview of the impact of ML integration in IBL and its implications for the development of learning methods in the future. Next. The criteria for the effect size value in this study can be seen in Table 1.

Tabel 1. Value Criteria Effect Size

Effect Size	**Kriteria**
0.0≤ES≤ 0.20	Low

0.20≤ES≤ 0.80	Medium
ES≥ 0.80	High

Source:(Ichsan et al., 2023; Bachtiar et al., 2023)

3. RESULT AND DISCUSSION

From the results of data search through databases related to the influence of the Machine Learning-assisted Inquiry Based Learning Model on Students' Problem-Solving Thinking Skills, 13 relevant studies were obtained. Furthermore, the effect size value of the 13 studies can be seen in Table 2.

Tabel 2. The Value of Effect Size Research

Journal Code	Variabel	Effect Size	Criterion
Y1	Problem Solving	0.71	Medium
Y2	Problem Solving	1.13	High
Y3	Problem Solving	0.62	Medium
Y4	Problem Solving	0.52	Medium
Y5	Problem Solving	0.75	Medium
Y6	Problem Solving	0.97	High
Y7	Problem Solving	1.18	High
Y8	Problem Solving	1.30	High
Y9	Problem Solving	1.07	High
Y10	Problem Solving	1.24	High
Y11	Problem Solving	1.92	High
Y12	Problem Solving	1.08	High
Y13	Problem Solving	0.76	Medium
Average Effect Size		**1.02**	**High**

Table 2, explains the average nilar of 13 effect sizes analyzed at 1.02. This finding explains that the inquiry-based learning model assisted by machine learning has a positive influence on students' problem-solving ability with high influencing categories. The use of the Machine Learning-assisted Inquiry-Based Learning (IBL) model in this study provides a new perspective on how to improve students' problem-solving thinking skills. The IBL model puts students at the center of the learning process by prioritizing exploration, investigation, and discovery (Siew & Chai, 2024). With the help of Machine Learning technology, this process becomes more directed and personalized, allowing students to understand the material in more depth. The results show that the integration of Machine Learning is able to provide fast and accurate data analysis, provide relevant feedback, and map students' learning needs based on identified patterns (Qamariyah et al., 2021).

The ability to think problem-solving is one of the most important 21st century skills to develop. The results of this study indicate that students who learn using the Machine Learning-based IBL model show a significant improvement in this ability. This is due to the existence of a data-based approach that allows teachers to design learning activities according to the level of ability of each student (Yustina et al., 2022). In addition, students are also given the

opportunity to explore various solutions using technology-based tools, so that they are able to develop better critical and analytical thinking skills (Boonsathirakul & Kerdsomboon, 2023).

The main advantage of Machine Learning in learning is its ability to personalize the learning experience. In this study, Machine Learning algorithms are used to identify students' difficulties in real-time and provide appropriate suggestions or recommendations. For example, if a student faces difficulties in understanding a particular concept, the system may recommend additional learning resources or practice relevant questions (Antonio & Prudente, 2023). This adaptive process not only helps students to understand the material better, but it also increases their confidence in solving problems. However, the application of Machine Learning in learning also presents several challenges. One of the main challenges found in this study is the need for adequate technological infrastructure. Schools that have limited access to high-quality hardware and software may face difficulties in implementing this learning model effectively (Adwiah et al., 2023). In addition, training for teachers to use this technology is also an aspect that needs to be considered. This research shows that technological support must be balanced with the development of human resource capacity so that the expected results can be achieved (Nasucha et al., 2023).

From a pedagogical perspective, the combination of IBL and Machine Learning also encourages a paradigm shift in the learning process. Teachers no longer only function as conveyors of information, but also as facilitators who help students explore their potential through the use of technology (Persaud & Persaud, 2019). This approach provides space for students to learn independently and collaboratively, so they can develop important interpersonal skills in the digital age. The results of this study support the importance of synergy between technology and learning methods to create a more meaningful learning experience (Wuryandani & Herwin, 2021).

Overall, this study provides empirical evidence that inquiry-based learning models supported by Machine Learning have great potential to improve students' problem-solving thinking skills (Yaqutunnafis, 2024). With the right implementation, this model can be an innovative solution to face educational challenges in the era of the Industrial Revolution 4.0. Therefore, the development of education policies that support the integration of technology in learning is urgently needed to ensure the sustainability and effectiveness of the implementation of this model.

Conclusion

From the results of this meta-analysis, it can be concluded that the inquiry-based learning model assisted by machine learning has a positive influence on students' problem-solving ability with an effect size value of 1,02 in the high effects size category. Through the integration of Machine Learning, learning becomes more personalized and adaptive, allowing students to overcome learning difficulties independently with data-driven recommendations. This model is also able to increase students' confidence and support the development of critical and analytical thinking skills, which are very relevant to face the challenges of learning in the digital era and the Industrial Revolution 4.0. However, the study also found that the successful implementation of this model depends on the readiness of adequate technological infrastructure and training for educators. Although these challenges are significant, the results indicate that with the support of supportive education policies and investment in technological and human resources, the Machine Learning-assisted Inquiry-Based Learning model has great potential to improve the quality of education as a whole and relevant to the needs of the 21st century.

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