

Integration of Artificial Intelligence in Higher Education to Enhance STEM Literacy: A Mixed-Methods Study

Sugiarto

Doctoral Program in Educational Administration, Graduate School, Pattimura University

Email: Sugiarto18@ymail.com

ABSTRACT

The integration of artificial intelligence in higher education has become an innovative strategy for enhancing students' STEM literacy in the digital era. This study aims to analyze the improvement of students' STEM literacy in AI-based learning and to examine students' perceptions of the use of artificial intelligence in the learning process. This study employed a mixed-methods approach with an explanatory sequential design. The participants consisted of 67 students from Abdul Muthalib Sangadji State Islamic University Ambon, Maluku. The research data comprised both quantitative and qualitative data collected through an online questionnaire survey and semi-structured interviews. The findings indicate that the integration of artificial intelligence in AI-based learning significantly improves students' STEM literacy, particularly in the areas of data analysis skills, problem-solving, and the critical use of technology. Students' perceptions of AI use tended to be positive, especially regarding ease of access to information and learning efficiency, although concerns remained about dependency and the decline of independent thinking skills. These findings confirm that the integration of artificial intelligence in AI-based learning is effective in enhancing students' STEM literacy. The implications of this research emphasize the necessity of developing learning strategies that promote the critical and reflective use of AI to support the quality of learning in higher education.

Keywords: artificial intelligence, STEM literacy, higher education

INTRODUCTION

The development of artificial intelligence (AI) has shifted the orientation of higher education from the digitalisation of learning toward the formation of more complex competencies, including digital literacy, AI literacy, and STEM literacy. However, the current use of artificial intelligence presents particular challenges (Balta, 2023). This perspective is in line with the views of Arini and Nursa'ban (2024), van den Berg and du Plessis (2023), and Cucci et al. (2025), who argue that the rapid development of artificial intelligence technologies, such as ChatGPT, recently has brought significant changes to the field of education. In the context of higher education, AI is no longer understood merely as an

administrative tool or a means of supporting productivity but also as a pedagogical instrument that can assist students in understanding concepts, analysing data, constructing arguments, and solving interdisciplinary problems. UNESCO emphasises the importance of grounding the use of generative AI in education in a human-centred vision, privacy protection, ethical validation, and responsible pedagogical design. This urgency is consistent with the demands of STEM literacy, namely the ability to use knowledge of science, technology, engineering, and mathematics to solve real-world problems, develop a STEM identity, and understand how STEM practices operate.

Recent literature indicates that the use of AI in higher education is developing rapidly. Kasneci et al. (2023) and Pudjiadi et al. (2024) argue that the integration of AI in education can enhance the effectiveness of instructional planning, enrich pedagogical strategies, and assist educators in managing administrative workloads. However, a key problem arises when the intensity of AI use lacks a clear pedagogical design aimed at improving STEM literacy. Students may use chatbots, AI-based search engines, or generative tools to complete assignments, but such use does not automatically produce conceptual understanding, scientific reasoning, engineering skills, or mathematical modelling. Although concerns have emerged that AI tools such as ChatGPT may weaken student productivity, research indicates that the use of AI in education can improve the efficiency and effectiveness of learning (Oğuz et al., 2023). This highlights the importance of supervision and ethical policies governing the use of AI in higher education institutions and other educational settings.

A general solution to this problem is to integrate AI as part of instructional design rather than treating it merely as an additional technology. AI should be positioned as a form of cognitive scaffolding that helps students explore concepts, obtain feedback, compare alternative solutions, and reflect on their thinking processes. This approach aligns with problem-based and project-based learning, as STEM literacy develops through activities such as identifying problems, evaluating evidence, creating models, designing solutions, and communicating arguments. Within this framework, a mixed-methods approach is relevant because the impact of AI cannot be adequately assessed through scores alone; it must also be understood through students' experiences, perceptions, and learning practices.

A more specific solution proposed in this study is the integration of AI into problem-based STEM activities. In this model, students do not merely request answers from AI but use it to formulate investigative questions, analyse data, test arguments, design prototypes, and revise solutions based on evidence. The role of lecturers is therefore essential as task designers, discussion facilitators, and guardians of epistemic standards. A number of previous international studies on the use of AI in education have shown that AI has become an influential technology in educational contexts. For

example, Christodoulou and Zembylas (2025) and Joyce (2025) examined students' emotional perspectives and the ethics of using ChatGPT in the classroom. Hadley-Hulet et al. (2024) also concluded that the integration of AI in education can lead to better outcomes in terms of subject-matter understanding and assignment writing. In Indonesia, studies by Marzuki et al. (2023) and Malik et al. (2023) indicate that the use of AI can change the way university and school students organise their thoughts, although it also creates challenges in understanding and applying the principles of effective academic writing.

Nevertheless, a research gap remains. Studies on AI in higher education have largely focused on technological functions, user acceptance, and general learning support, while empirical evidence on the integration of AI to improve STEM literacy remains limited. Based on this background, this study formulates two research questions to address the identified gap:

1. To what extent does the integration of artificial intelligence into AI-based learning contribute to improving students' STEM literacy in higher education?
2. How do students perceive the use of artificial intelligence in the learning process?

Through these research questions, this study aims to analyse the integration of artificial intelligence in higher education to improve students' STEM literacy using a mixed-methods design. Quantitatively, this study examines changes in STEM literacy after AI-integrated learning; qualitatively, it explores students' perceptions, strategies, and challenges in using AI for STEM activities. The novelty of this study lies in the integration of AI literacy and STEM literacy within a single instructional design that positions AI as cognitive scaffolding, a reflective tool, and a means of scientific verification. The scope of the study is limited to the context of higher education and focuses on students' STEM literacy, rather than on the technical evaluation of AI algorithms.

METHODOLOGY

This study employed a mixed-methods approach with a sequential explanatory design, in which quantitative data collection and analysis were conducted first, followed by qualitative data collection to further explore and explain the survey findings. This design was selected because the study aimed not only to describe patterns of artificial intelligence use, particularly ChatGPT, in students' academic activities, but also to understand the experiences, perceptions, and ethical considerations associated with its use in higher education learning. This approach is consistent with Creswell's (2009, as cited in Pudjiadi et al., 2024) view that a sequential explanatory design allows quantitative data to provide a general overview, while qualitative data help explain the meaning and context of the findings. The main variable in this study was the integration of artificial intelligence into higher education learning to support students' STEM literacy. The research

instruments consisted of an online questionnaire and a semi-structured interview guide. The online questionnaire contained 18 closed-ended and semi-open-ended questions developed based on research indicators and relevant literature on the use of AI in education. A Likert scale was used because it is considered capable of quantitatively measuring students' perceptions and attitudes, is easy to administer in online surveys, and enables both descriptive and inferential statistical analysis.

The instrument development process included identifying indicators, formulating question items, conducting content validation by two experts in language education and technology, revising the instrument based on expert feedback, and conducting a limited trial with ten students. Instrument validity was assessed through content validity, while reliability was tested using Cronbach's alpha, with a value of ≥ 0.70 considered acceptable, as suggested by Nunnally (1978). Meanwhile, the interview guide was developed based on the survey results to explore students' experiences using ChatGPT, their strategies for utilizing AI, the challenges they encountered, and their ethical views on AI use. The population of this study consisted of undergraduate students at Abdul Muthalib Sangadji State Islamic University of Ambon. In the quantitative phase, the study employed purposive sampling with the criteria that participants had experience using ChatGPT and were involved in writing scientific papers or completing academic assignments. A total of 67 students participated in the survey. In the qualitative phase, four students were selected from the survey participants by considering variations in semester level, experience in using AI, and type of scientific writing. Data were collected online.

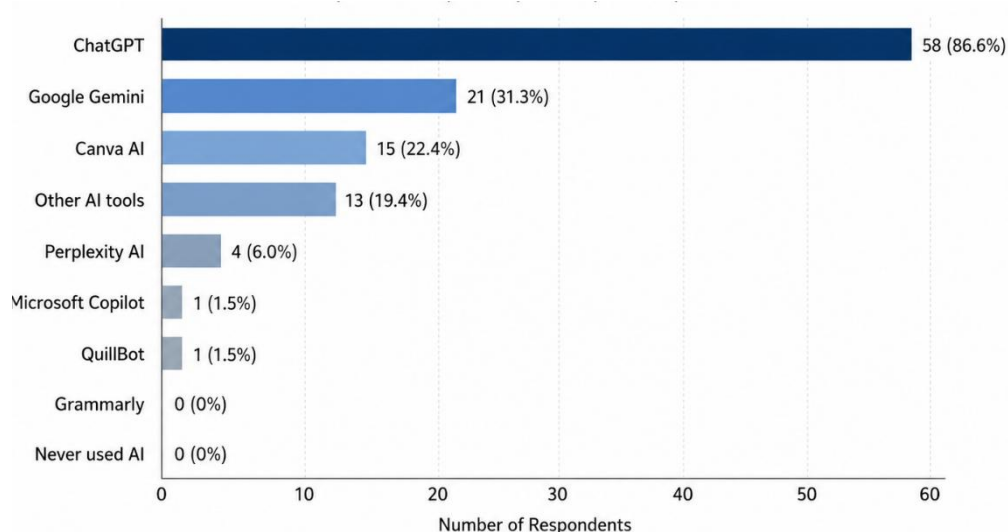
The quantitative survey was conducted over two weeks in March 2026 through Google Forms, which was distributed to students via WhatsApp groups. Google Forms was selected because it facilitated instrument distribution, real-time response monitoring, and data completeness checking. After the survey was completed, qualitative interviews were conducted in April 2026 via Zoom, with each interview lasting approximately 30–45 minutes. The interviews were recorded with participants' consent and transcribed verbatim. To ensure research ethics, each participant was provided with informed consent containing an explanation of the research objectives, the right to decline answering certain questions, and assurance of data confidentiality. Quantitative data were analyzed using descriptive statistics, including frequencies, percentages, and means, as well as inferential analyses such as correlation tests and difference tests to identify patterns of AI use in supporting STEM literacy. Data processing was carried out using Microsoft Excel, as the software provides basic statistical functions that are adequate for the needs of survey analysis. Thus, the mixed-methods approach employed in this study enabled a more comprehensive understanding of how artificial intelligence is used in higher education and how its use contributes to improving students' STEM literacy.

RESULTS AND DISCUSSION

1. Integration of Artificial Intelligence in AI-Based Learning to Improve STEM Literacy

The following figure illustrates the percentage of students using AI in their learning, based on the research findings.

Figure 1:
Intensity of AI Use Among Students



Based on Figure 1, the integration of AI in learning appears to fall within a high category. In terms of the types of AI applications used, ChatGPT was the most dominant application, used by 58 students, or 86.6%. Other applications used included Google Gemini by 21 students, or 31.3%; Canva AI by 15 students, or 22.4%; other AI applications by 13 students, or 19.4%; Perplexity AI by 4 students, or 6.0%; and Microsoft Copilot and Quillbot, each used by 1 student, or 1.5%. All students reported that they had used AI. The dominance of ChatGPT as the most widely used application indicates that students tend to utilize generative AI as a conversational learning partner. In the context of STEM literacy, the finding is important because generative AI enables students to ask questions, request further explanations, seek examples, formulate problem-solving steps, and obtain rapid feedback. The literature on AI in education suggests that AI has the potential to support more personalized, adaptive, and interactive learning, although its use still needs to be pedagogically guided.

The survey results on the STEM literacy dimension showed that the overall mean score of students was 3.92 on a 5-point scale, indicating a positive tendency. In aggregate, 71.2% of responses were in the agree and strongly agree categories, 25.8% were neutral, and only 3.0% were in the disagree or strongly disagree categories. This suggests that the majority of students perceived AI as beneficial in supporting learning processes related

to STEM. The indicator with the strongest response was AI's ability to help students analyze data or information in coursework, with 82.1% of respondents stating that they agreed or strongly agreed. Other indicators that also received high responses included AI's role in helping students find scientific information relevant to learning materials, at 79.1%; assisting in developing ideas, analyses, or solutions in STEM assignments, at 77.6%; and improving critical thinking skills regarding the information obtained, at 74.6%. For greater clarity, the survey data on AI use in enhancing STEM literacy are presented in the following table.

Table 1:
Survey of AI-Based STEM Literacy

Indicators of AI-Based STEM Literacy	Average	Agree + Strongly Agree
AI supports the search for relevant scientific information.	4,07	79,1%
AI assists in analyzing data or task-related information.	4,04	82,1%
AI enhances critical thinking in evaluating information	4,01	74,6%
AI helps formulate ideas, analyses, or solutions.	4,00	77,6%
AI supports the understanding of STEM concepts.	3,99	74,6%
Students are able to compare AI-generated responses with other sources.	3,94	74,6%
AI assists in solving STEM-related problems.	3,87	62,7%
AI improves digital technology skills.	3,76	65,7%
AI increases students' confidence in learning STEM.	3,75	62,7%
AI connects STEM concepts with real-world problems.	3,73	58,2%

An intriguing finding is the pattern of increasing STEM literacy scores based on the intensity of AI use. Students who used AI monthly had a mean STEM literacy score of 3.74; weekly users scored 3.97; and daily users scored 4.14. The ordinal correlation between the intensity of AI use and STEM literacy scores was $r = 0.327$, indicating a moderate positive relationship. However, the findings also reveal an uneven distribution of AI's contribution across various aspects of STEM literacy. The indicator with the lowest score was the ability to connect STEM concepts with real-life problems, with an agreement level of 58.2%, followed by increased confidence in learning STEM, with 62.7%. This suggests that AI is more effective in assisting students at the level of accessing information, explaining concepts, and constructing answers, but it still needs to be

further encouraged to genuinely support students in transferring knowledge to real-world contexts.

Therefore, lecturers need to design AI-based learning that does not stop at answer-seeking activities but is directed toward projects, case studies, problem-solving, source verification, and critical reflection. Another important aspect is students' critical attitudes toward AI. The data show that the mean score of students' critical attitudes was 4.17 out of 5, with 84.0% of responses falling into the agree and strongly agree categories. The highest indicator was the statement that students use AI as an assistive tool rather than as a substitute for thinking, with a mean score of 4.40 and an agreement level of 92.5%. This finding reinforces the idea that students are not only using AI technically but are also beginning to understand the need for critical control over AI-generated outputs. Thus, the integration of AI into STEM learning cannot be achieved merely by providing access to applications; it must also be accompanied by ethical literacy, the ability to verify the accuracy of information, and the habit of comparing AI-generated answers with other academic sources.

2. Students' Perceptions of the Use of Artificial Intelligence in the Learning Process

Based on open-ended interview data from four respondents, students demonstrated generally positive perceptions of the use of artificial intelligence in STEM learning. AI was viewed as an assistive tool that can accelerate understanding, facilitate problem-solving, support data analysis, and enhance technology-related skills. However, students also recognized several risks, such as dependency, decreased critical thinking ability, information inaccuracy, and potential violations of academic integrity. The following section presents students' perceptions based on the interview findings.

AI as an Assistive Tool for Understanding Complex STEM Concepts

The first finding indicates that students perceive AI as a medium that helps them understand difficult STEM concepts, particularly in the fields of mathematics, science, technology, and engineering. Students considered AI capable of simplifying learning materials, providing interactive explanations, and presenting simulations or visualizations that make abstract content more concrete. This is reflected in the following excerpts:

R1: It helps make difficult concepts easier to understand, presents engaging data visualizations, and accelerates calculation and analysis processes, making learning more effective and efficient.

R2: In my opinion, the main benefit of using AI in STEM learning is that it helps students understand material more quickly through interactive explanations, provides simulations or visualizations of difficult concepts, and supports independent learning according to each student's ability."

These excerpts show that AI is not merely perceived as a tool for finding answers but also as a support for the process of conceptual understanding. In the context of STEM literacy, the ability to understand abstract concepts is essential because students are not only expected to memorize theories but also to connect concepts with real-world problem-solving. In addition, AI is perceived as helping students learn independently according to their individual needs. This is supported by the findings of Kasneci et al. (2023), who reported that AI has the potential to provide sources of ideas, text models, and varied learning materials that support the learning process. The respondents in this study also reinforced this statement through the following data:

R3: AI can explain difficult concepts, such as calculus or quantum physics, in simple language whenever I need it. If I become stuck working on a problem at 1 a.m., I can still ask for help.

R3's statement illustrates that AI provides learning flexibility. Students can access assistance at any time, especially when they encounter difficulties in understanding course material outside regular lecture hours. Thus, the integration of AI in higher education has the potential to expand access to STEM learning that is more adaptive, personalized, and independent.

AI Supports the Enhancement of STEM Literacy through Data Analysis, Problem-Solving, and Technological Skills.

The second finding indicates that students perceive AI as beneficial in improving their abilities in data analysis, problem-solving, and the use of technology. These three aspects are relevant to the objective of enhancing STEM literacy in higher education. The following statements from respondents reflect this:

R4: Yes, it is very beneficial. "AI makes it easier to process data quickly, provides alternative solutions, and helps me become more familiar with and proficient in using modern technology.

R2: The main benefit of using AI in STEM learning is that it helps me develop ideas, conduct analysis, and formulate solutions.

These excerpts show that AI plays a role in assisting students in structuring their thinking, identifying alternative solutions, and understanding analytical processes. In the context of STEM learning, these abilities are important because students are required to process information, interpret data, and solve problems systematically. AI also helps students become familiar with certain technological tools or applications. The following excerpt illustrates this concept:

R1: AI helps me learn to write Python or R code more quickly and shows me how to use libraries like pandas. I can understand the workflow even though I initially did not understand it."

This excerpt demonstrates that the use of AI can promote students' technological literacy, particularly in the use of programming languages and data analysis tools. Thus, AI functions not only as a source of information but also as a learning companion that helps students understand technical procedures in STEM practice.

Students' Difficulties in Using AI: Accuracy, Prompting, Access, and Dependence

Although students perceive AI as a useful tool, they also experience several challenges in using it. The main difficulties identified include the inaccuracy of AI-generated responses, the need to formulate appropriate prompts, limited internet access or access to paid features, and the potential for dependence. The following respondent statements support these findings.

R3: Sometimes the information provided is not necessarily 100% accurate and needs to be rechecked. It can also make us less trained in independent thinking if we rely on it too much.

R4: AI often provides answers that seem convincing but are actually wrong, especially for calculation problems or specific scientific facts. We always need to double-verify.

These two quotations indicate that students are aware of the risk of misinformation generated by AI. In STEM learning, the accuracy of data, formulas, scientific facts, and calculation processes is highly important. Therefore, the use of AI must be accompanied by the ability to verify information through other sources, such as books, journals, lecturers' teaching materials, or classroom discussions.

Concerns Regarding the Use of AI in Higher Education

The next finding shows that students' main concerns are related to dependence, a decline in critical thinking, plagiarism, and the misuse of AI in academic assignments. Students recognize that AI can facilitate learning, but it may also create problems if used without academic ethics. The following respondent statement reflects this concern.

R1: I am concerned that students may become too dependent on it, causing their critical thinking skills and creativity to decline. In addition, there is a risk of misuse for cheating, as well as concerns about the accuracy of information and copyright issues.

This quotation shows that students view academic integrity as an important issue in the use of AI. AI can support the learning process, but it can also be misused to generate assignments instantly. If this misuse occurs, students may obtain final answers without understanding the underlying concepts, processes, and arguments. The following quotation highlights

another concern.

R2: My concern is that the knowledge will not really enter my mind.

This statement illustrates that excessive use of AI may cause students to focus only on obtaining answers rather than engaging in the learning process. In the context of higher education, this issue becomes an important challenge because the quality of learning is not only measured by task completion but also by students' ability to understand, analyze, and apply knowledge. This finding is in line with the views of Nursalam et al. (2025) and Yuliani et al. (2023), who state that academic integrity is a fundamental principle that students, as ChatGPT users, must uphold to maintain high academic standards. Thus, the integration of artificial intelligence in higher education has immense potential to improve students' STEM literacy when used in a directed, critical, and ethical manner. AI can serve as a learning companion that helps students understand concepts, process data, solve problems, and improve technological skills. However, without proper guidance, AI may also lead to dependence, plagiarism, a decline in critical thinking, and weakened academic integrity. Therefore, AI-based learning in higher education needs to be designed according to the principle of balance: utilizing technological sophistication while continuing to position students as active subjects who think, analyze, and take responsibility for their learning process.

CONCLUSION

This study demonstrates that the integration of artificial intelligence into higher education learning contributes positively to the enhancement of students' STEM literacy. The quantitative findings indicate that students show a positive tendency to use AI, particularly for searching scientific information, analyzing data, developing ideas, understanding STEM concepts, and solving academic problems. The positive relationship between the intensity of AI use and STEM literacy scores suggests that the more frequently students use AI in a purposeful manner, the greater the opportunity to strengthen their analytical skills, problem-solving abilities, and technological literacy. The qualitative findings further support these results by showing that students perceive AI as a flexible, personalized, and efficient learning tool. AI helps simplify complex STEM concepts, provides alternative solutions, and supports independent learning. However, this study also identifies several important challenges, including the risk of dependence, information inaccuracy, weak source verification, and the potential violation of academic integrity. The implication is that AI should be integrated not as a substitute for students' thinking processes or the role of lecturers, but as a form of cognitive scaffolding that encourages analysis, reflection, and scientific verification. This study contributes to the broader understanding of AI's role as cognitive scaffolding in STEM learning, particularly in terms of how students use AI to understand concepts,

analyze data, formulate solutions, and address ethical and academic challenges in its use. Future research is recommended to explore more structured, interdisciplinary, and project-based AI-supported learning models in order to examine their impact on critical thinking, creativity, and the transfer of STEM knowledge to real-world problems.

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