



The Role of AI in Promoting Learning Independence and Scientific Explanation Ability among Physics Education Students

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ABSTRACT

Integrating Artificial Intelligence (AI) in higher education has transformed learning processes, particularly in complex subjects like physics. This study investigated the implications of AI utilization, specifically generative tools such as ChatGPT on two key aspects of physics education: students' learning autonomy and scientific explanation skills. A descriptive quantitative approach was employed, surveying 50 pre-service physics teachers from universities in Aceh, Indonesia, using a structured questionnaire. The findings revealed that while AI tools support students in understanding concepts and completing assignments, there is a notable gap in fostering deep conceptual engagement and critical thinking. Most respondents (45%) agreed that AI aids learning autonomy, yet only 20% strongly agreed, suggesting a partial dependence on AI without fully developing independent learning skills. Similarly, only 35% agreed, and 17% strongly agreed that AI enhances scientific explanation abilities. Analysis indicated a positive correlation between learning autonomy and explanation skills, though not linear, highlighting potential overreliance on AI-generated solutions at the expense of reflective reasoning. The study underscored the importance of designing pedagogical strategies that balance AI integration with cultivating critical, reflective, and exploratory thinking. These insights contributed to the growing discourse on AI's role in physics education and its impact on students' cognitive and conceptual development.

Keywords: artificial intelligence, learning Independence, scientific explanation, ChatGPT

1. INTRODUCTION

The rapid development of artificial intelligence (AI) technologies has transformed various domains of life, including higher education. AI-powered tools such as chatbots, intelligent tutoring systems, and generative models like ChatGPT are increasingly being used by university students to complete assignments, comprehend complex topics, and solve academic problems, even in demanding disciplines such as physics (Ahuja, 2019; Veloso et al., 2021). These tools offer fast and seemingly convincing answers. However, they risk undermining students' scientific reasoning and learning autonomy when used without sufficient conceptual understanding.

Although several studies highlight the positive impact of AI integration on student motivation and learning efficiency (Bitzenbauer, 2023), other findings emphasized its potential cognitive drawbacks. For instance, Krupp et al. (2023) revealed that nearly half of the physics solutions provided by ChatGPT were judged correct by students despite being scientifically inaccurate. This indicates a worrying trend, in which students tend to accept AI-generated responses uncritically. Similarly, Forero & Suárez (2023) reported that students who relied on ChatGPT demonstrated lower academic performance than those taught using traditional methods.

Furthermore, applying large language models (LLMs) in education presents challenges related to misinformation, source credibility, and lack of conceptual understanding (Floridi & Chiriatti, 2020; Lecler et al., 2023). In content-heavy fields like physics, conceptual depth and context awareness are critical (Gao et al., 2023; Whalen & Mouza, 2023). Overdependence on AI-generated content can diminish students' engagement in active knowledge construction and their development of scientific explanation skills.

Recent scholarship has begun to evaluate generative AI's role in science education critically. Research has shown both the promise and perils of AI-assisted learning ranging from improved accessibility to the erosion



of reflective thinking (Wang, 2023; Kasneci et al., 2023). However, most existing studies focus on general student perceptions or AI's functional accuracy. Few delve into the pedagogical implications for disciplines such as physics, particularly regarding how AI affects students' learning autonomy and ability to articulate scientific explanations.

To date, there is a lack of empirical research investigating the dual impact of AI use on learning independence and scientific explanatory competence within pre-service physics teacher education. This study aims to fill that gap by providing discipline-specific insights into the cognitive and behavioral shifts prompted by AI-assisted learning. The novelty of this research lies in its focus on physics education students' reliance on generative AI and how such reliance shapes their ability to construct and communicate scientific concepts independently, an area yet to be systematically explored in the current literature.

This study investigates the implications of AI usage on university students' learning autonomy and scientific explanation ability, specifically within physics education. The findings are expected to inform future instructional strategies that harness AI's potential without compromising students' critical thinking and conceptual mastery.

2. METHODS

This study adopted a quantitative descriptive approach using a survey method to explore the extent to which university students depend on artificial intelligence (AI) tools, particularly generative models such as ChatGPT, in their physics learning process. The descriptive design is suitable for identifying patterns and tendencies within a population and is often used to measure attitudes, perceptions, and behaviors in education (Creswell, 2014). Fifty physics education students from various Aceh, Indonesia universities were selected through a simple random sampling technique. This allowed for a diverse representation of students with varying exposure to and experience with AI technologies.

The main instrument used was a structured, closed-ended questionnaire comprising 10 items; each aimed at capturing students' perceptions and usage of AI in tasks such as understanding concepts, solving problems, and completing assignments. The questionnaire employed a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). To ensure validity, the questionnaire was reviewed and refined with the input of three experts in educational technology and physics education, aligning with best practices in instrument development (Fraenkel et al., 2012).

The data were collected online via Google Forms over one week. Respondents were informed of the study's objectives, assured of the anonymity and confidentiality of their responses, and reminded of their right to withdraw at any time. The responses were then analyzed using descriptive statistics, focusing on percentage distributions to identify response patterns. The results were presented through tables and bar charts, clearly representing students' dependence levels. These were further categorized as low, moderate, or high based on cumulative Likert scores, a common strategy in educational survey analysis.

3. RESULTS & DISCUSSION

This study examined the implications of AI utilization on two critical aspects of physics learning: students' learning autonomy and their scientific explanation skills. Based on questionnaire data collected from 50 respondents, the following summary was obtained:



Table 1. Summary of Student Responses

Response Category	Learning Autonomy (%)	Scientific Explanation (%)
Strongly Disagree	5	8
Disagree	10	15
Neutral	20	25
Agree	45	35
Strongly Agree	20	17

Table 1 above shows that most students reported *Agree* (45%) regarding the role of AI in supporting their learning autonomy. However, only 20% expressed *Strongly Agree*. This suggests that while AI does assist the learning process, it has not yet fully developed optimal learning independence. Meanwhile, for scientific explanation skills, only 35% responded *Agree*, and 17% *Strongly Agree*, with 25% remaining *Neutral*. To further analyze the relationship between these two variables, the following figure illustrates the pattern:

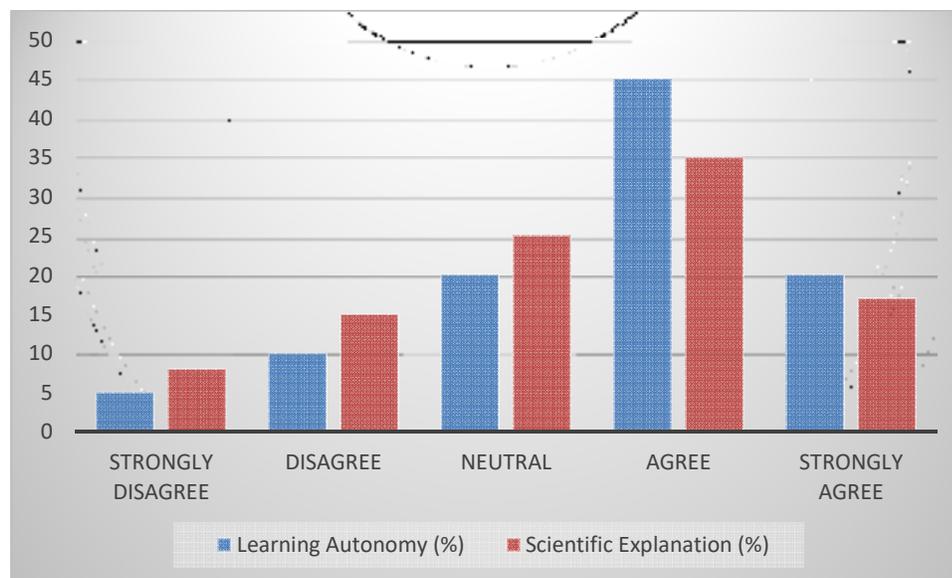


Figure 1. Respondents' Results on AI Usage

The figure shows the relationship pattern between the two variables: the higher the percentage of positive responses toward learning autonomy, the more likely it is to be accompanied by positive responses toward scientific explanation skills. However, the data points at Strongly Agree indicate that increased learning autonomy does not always correlate linearly with increased scientific explanation skills. This reinforces the notion that AI has not fully encouraged students to develop a deep understanding of physics concepts but rather tends to support the completion of technical tasks.

Several factors contributing to this imbalance can be traced to students' tendency to overly rely on instant answers from AI without engaging in reflective thinking processes. This aligns with the findings of Krupp et al. (2023) and Forero & Suárez (2023) who emphasized that passive use of AI may hinder the development of scientific reasoning and lead students to become quickly satisfied with surface-level answers. Additionally, AI tools such as ChatGPT still face limitations in comprehensively comprehending the context and structure of



physics concepts (Gao et al., 2023). Consequently, when AI is used without pedagogical guidance, it may reduce students' intellectual exploration capacity.

Integrating Artificial Intelligence in digital learning environments has become a notable trend in contemporary education, presenting opportunities and challenges for student learning outcomes (Ronsumbre et al., 2023). AI tools are being utilized to personalize learning experiences, automate administrative tasks, and provide students with immediate feedback, potentially reshaping the dynamics of traditional educational settings (Huda & Suwahyu, 2024). Examining how these technological advancements affect students' self-directed learning skills and their capacity to articulate scientific concepts effectively. The pervasive use of AI as a learning aid could impact students' intrinsic motivation to learn, potentially fostering a reliance on technology for problem-solving rather than cultivating independent critical thinking. Furthermore, the capacity of students to explain scientific ideas may be hampered by AI-driven tools if these technologies perform explanations instead of requiring students to engage in sense-making and articulation processes actively (Rana et al., 2024). One significant area of concern is the potential impact of AI on the development of self-regulated learning strategies among students. Self-regulated learning involves students' ability to monitor, control, and evaluate their learning processes, including goal setting, strategy selection, and self-assessment.

Thus, these findings demonstrate that while AI can serve as a powerful learning aid, the context and manner of use are crucial in determining whether AI promotes or hinders students' academic development. Physics instructors and curriculum developers must actively design pedagogical approaches that encourage the use of technology and foster a culture of critical, exploratory, and scientific thinking among students.

4. CONCLUSION

Based on the survey results and descriptive analysis, the use of AI in physics learning significantly impacts students' learning autonomy and scientific explanation skills. Most students find AI helpful in understanding materials and completing assignments. However, there is also an indication that excessive reliance on AI may weaken students' critical thinking abilities and conceptual exploration. Therefore, instructors and educational institutions must design learning strategies that facilitate a balanced and responsible use of AI while promoting the enhancement of scientific literacy and students' conceptual reflection.

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