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Identification of Generative AI Usage Profiles and Implications for Critical Thinking Skills in Physics Learning

Aminudin Zakaria[1], Budi Jatmiko[1], Binar Kurnia Prahani[1*], Cahyo Febri Wijaksono[2]
[1]Universitas Negeri Surabaya, Surabaya, Indonesia
[2]Universität für Weiterbildung Krems, Krems an der Donau, Austria

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ABSTRACT

Objective: *This study aims to map students' GenAI usage profiles during physics learning. In addition, it examines the correlation between these variables and students' critical thinking skills in physics learning.* ***Method:*** *A non-experimental, quantitative, ex post facto design was employed. This design captures phenomena that occur naturally without any intervention. The research instruments consisted of questionnaires and tests. Data were analyzed using descriptive statistics, the Kruskal–Walls test, and Spearman's correlation test.* ***Results:*** *Students tend to accept answers from GenAI quickly during physics learning. Only a small proportion are accustomed to questioning, verifying, and evaluating GenAI-generated answers. There are differences in critical thinking skills among groups of students with different patterns of GenAI use, with an* ε^2 *of 0.410. The profile of GenAI usage is positively correlated with critical thinking skills, with a correlation coefficient of 0.525, indicating a moderate relationship.* ***Novelty:*** *This study contributes by revealing students' GenAI usage profiles in physics learning and by providing empirical evidence that the quality of ethical and reflective use has a strong influence and is positively correlated with critical thinking skills.*

INTRODUCTION

Critical thinking remains an urgent skill for students to master in the 21st century. Critical thinking skills (CTS) are vital for interpreting and evaluating information, making decisions, and solving problems, which are frequently used in everyday activities (Saikia & Roy, 2024; Trúsiková & Velmovská, 2022). Furthermore, in the modern era, critical thinking is crucial for navigating the complexities and challenges posed by rapidly changing situations driven by various technologies (Wheatley & Hervieux, 2025).

Technological development is inseparable from physics as a fundamental aspect (Gaurina et al., 2022). Furthermore, physics is an appropriate vehicle for practicing higher-order thinking skills, such as critical thinking and problem-solving (Mitrevski, 2019). However, recent research reports that students' thinking skills, particularly those specifically in the context of physics learning, remain low (Deta et al., 2024; Lintangesukmanjaya et al., 2025; Neswary et al., 2023; Saphira et al., 2022; Wulandari et al., 2021). Efforts or innovations in physics learning are needed to improve critical thinking skills.

One learning innovation shown to improve critical thinking skills is the problem-based learning (PBL) model (Anggraeni et al., 2023; Yu & Zin, 2023). The main characteristic of the PBL model, which requires students to engage actively in investigation and problem-solving, ultimately leading to decision-making, is a factor that makes it effective in improving critical thinking skills (McConnell et al., 2018; Miterianifa et al., 2021). So, if the core spirit of PBL is not implemented, its effectiveness in improving critical thinking skills will decrease. Concerns about the declining effectiveness of the PBL model are further borne out by the advent of Generative Artificial Intelligence (Gen AI) technology,

which students use to outsource tasks such as writing and problem-solving (Allen et al., 2025; Garcia Ramos & Wilson-Kennedy, 2025). The emergence of Gen AI and its implications for education have drawn dystopian, utopian, and ambiguous responses from academics, educators, and policymakers (Driessens & Pischetola, 2024; Williamson, 2024). In response, UNESCO has developed a framework for Artificial Intelligence in Education (AIEd) that includes competencies for evaluating and critiquing AI-generated outputs or answers (Miao et al., 2024).

However, recent research focuses on the impact of Gen AI implementation on the mastery and understanding of physics concepts. For example, research by Coban et al. (2025) reported that students who received formative feedback from ChatGPT 4o had a higher understanding of physics concepts (quantum physics) than the group without feedback. Another study, conducted by Fathi et al. (2025), reported that the group receiving scaffolding assistance from ChatGPT achieved statistically significant gains compared to the control group. A comprehensive research approach in education should not stop at mastering cognitive concepts but should systematically focus on developing critical thinking skills to meet the demands of the 21st century.

Dahlkemper et al. (2023) conducted research focused on developing critical thinking skills in physics learning, but did not explicitly measure them. In their research, Dahlkemper et al. (2023) reported that students still had difficulty evaluating ChatGPT responses, especially on high-level physics problems (fluids). Furthermore, students' prior content knowledge significantly influenced their ability to evaluate Gen AI's answers. Measurement of critical thinking skills has not yet been conducted. Their research suggests that Gen AI's answer evaluation activity has the potential to train critical thinking skills.

Despite the potential to improve critical thinking skills, Gen AI interventions in learning remain impractical due to a lack of empirical baseline data. This research gap is characterized by the lack of empirical knowledge regarding students' Gen AI usage patterns, particularly regarding how they utilize Gen AI to complete physics assignments. It is necessary to identify whether Gen AI is used as a substitute tool or as a means of exploration, evaluation, and reflection that reflects a level of cognitive depth.

Theoretically, the use of Gen AI in student learning can improve their critical thinking skills among students with strong self-regulation (Zhang & Liu, 2025). Therefore, it is necessary to identify students' baseline profiles (without intervention) and the correlation between these profiles and the two variables. This study will provide an empirical basis by examining the relationship between Gen AI usage profiles and critical thinking skills to inform the design of Gen AI-based learning and 21st-century competencies. Based on this background, this study focuses on answering the following research questions:

- RQ1: What is the profile of students' Gen AI usage in physics learning?
- RQ2: Are there differences in critical thinking skills based on the level of Gen AI usage?
- RQ3: How is the relationship between the level of Gen AI usage and students' critical thinking skills?

RESEARCH METHOD

General Background

This study employed a non-experimental, quantitative, ex post facto design. This design was used because no treatment was administered to the sample, and the research was causal-comparative, based on actual field conditions (Silva, 2010). This study identified the profile of Gen AI usage that had occurred naturally among students. The data were

then analyzed for differences in critical thinking skill levels and the relationships between these variables.

This study measured two variables: the Gen AI usage profile (X, independent variable) and critical thinking skills (Y, dependent variable). The Gen AI usage profile was identified based on the patterns and levels of student utilization during physics lessons. These patterns and utilization levels were then classified into several use categories. Critical thinking skills were measured based on indicators operationalized in the research instrument.

Participants

This study involved 56 eleventh-grade students at a public high school located in the suburban area of Jombang Regency, Indonesia. The school and participants were selected purposively, given that the school's physics teacher had permitted students to use Gen AI to complete learning assignments and as a personal assistant when students struggled with concepts. This case was deemed relevant to the research objective, which was to identify Gen AI usage profiles without providing treatment. All participants had experience using Gen AI before data collection. The participant distribution consisted of 31 female students (55%) and 25 male students (45%).

Instrument and Procedures

Gen AI usage profiles were measured using a seven-item questionnaire. Participants completed the questionnaire using a 4-point Likert scale. Prior to data collection, the questionnaire was tested for validity and reliability, with an Aiken V of 0.87 and a Cronbach's α of 0.643. These reliability coefficients indicate that the questionnaire has sufficient internal consistency. In exploratory research using a new questionnaire, these coefficients were still acceptable (Hair et al., 2010). Meanwhile, the critical thinking skills test instrument was developed based on indicators from Facione (2013), which consist of interpretation, analysis, evaluation, inference, explanation, and self-regulation. However, this study did not measure the self-regulation indicator because it is difficult to assess via a written test. Prior to data collection, the test instrument was tested for validity, with an Aiken V value of 0.85. Reliability was determined using the intra-rater reliability method by reassessing the sample responses after a two-week interval.

Data Analysis

Before data analysis, clustering was performed to group the Gen AI usage profiles into three levels. Clustering used the criteria in Table 1. A prerequisite test, namely normality, was conducted first to determine the appropriate type of statistical test. If the data met the prerequisite test assumptions, parametric statistics were used. Non-parametric statistics were used if the prerequisite test assumptions were not met. All statistical tests were performed using Jamovi software version 2.6.44. To answer the RQ, ANOVA will be used to determine differences between groups, and Pearson's correlation test will be used to determine relationships between variables. Meanwhile, the Kruskal-Walls test and Spearman's correlation test will be used as substitutes when the data do not meet the prerequisite assumptions. The magnitude of the correlation between Gen AI usage profiles and critical thinking skills is interpreted in Table 2.

Table 1. Criteria for classifying gen AI usage profiles

Criteria	Category	Description
$Mean + SD < x$	HIGH	Students demonstrate a reflective, critical attitude toward Gen AI's answers through an active search for understanding and self-evaluation.
$Mean - SD \leq x \leq Mean + SD$	MEDIUM	Students often use AI as a functional tool and quickly accept answers without conducting an in-depth examination.
$x < Mean - SD$	LOW	Students use Gen AI passively and tend to accept answers without conducting in-depth verification and evaluation.

Table 2. Criteria for interpreting correlation (Gravetter & Wallnau, 2016)

Correlation Coefficient	Interpretation
0.90 – 1.00	Very Strong
0.70 – 0.89	Strong
0.50 – 0.69	Moderate
0.30 – 0.49	Low
0.00 – 0.29	Very Low

RESULTS AND DISCUSSION

Results

Data on Gen AI usage profiles were collected through a questionnaire, and data on critical thinking skills were collected through a test. The results are reported in Table 3.

Table 3. Descriptive statistics of data collection results

	Gen AI Profile	CT Skill
N	56	56
Mean	20.1	46.8
Median	21.0	45.0
Standard deviation	1.62	5.59
Variance	2.62	31.3
Shapiro-Wilk W	0.839	0.883
Shapiro-Wilk p	<.001	<.001

In this study, the results from 56 respondents showed that students' critical thinking skills scores had less variation than those on the Gen AI usage profiles. The standard deviation for critical thinking skills scores was also larger than for the Gen AI usage profiles. However, both data distributions were mostly close to the mean. The Shapiro-Wilk normality test yielded a p-value < .001, indicating that the data did not meet the normality assumption. Therefore, non-parametric statistical tests will be used in the next stage.

To ensure the internal validity of the data to be analyzed, a reliability test was conducted on the Gen AI usage profile data, yielding a Cronbach's α coefficient of 0.643. This reliability coefficient indicates that the questionnaire results have sufficient internal consistency. In exploratory research using a new questionnaire, this coefficient is still acceptable (Hair et al., 2010). Meanwhile, the critical thinking skills score obtained an intra-rater reliability coefficient of 0.948 with a percentage agreement of 94.2%. Based on these results, the data were deemed suitable for further statistical testing.

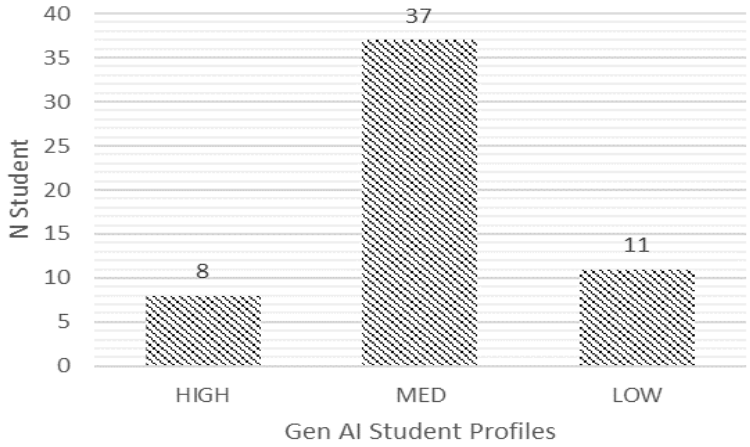

Figure 1. Results of grouping students' gen AI usage levels

Grouping was performed based on the mean and standard deviation. The grouping results are shown in Figure 1. A total of 8 respondents were in the high-usage group, while 11 were in the low-usage group. This distribution applies to the respondent groups in this study. Differences in school environment and region can produce different distributions.

Table 4. Results of the Kruskal–Walls test

	χ^2	df	p	ε^2
CT Skill	22.5	2	<.001	0.410

Table 5. Post Hoc test results

		W	p
MEDIUM	***HIGH***	6.43	<.001
MEDIUM	***LOW***	-1.40	0.582
HIGH	***LOW***	-5.34	<.001

The Kruskal-Walls test was conducted on critical thinking skill scores for the three groups of students using Gen AI. The results of the Kruskal-Walls test are shown in Table 4 and obtained a p-value <0.001 with an effect size coefficient of ε^2 of 0.410. Based on these results, there is a significant difference in the average critical thinking skills of the three groups (High, Medium, and Low). Therefore, to determine differences between groups, a post hoc test was conducted using the Dwass-Steel-Critchlow-Fligner (DSCF) pairwise comparisons method, with the results shown in Table 5.

Based on the results of the difference test in Tables 4 and 5, a Spearman correlation test was conducted between the Gen AI usage profile variables and critical thinking skills. The results of the Spearman correlation test are shown in Table 6. The results in Table 6 yield a correlation coefficient of 0.525 (p-value < 0.001). Interpreted according to the criteria in Table 2, this correlation coefficient is classified as moderate.

Table 6. Results of the Spearman Correlation test

		CT Skill
Gen AI Profile	**Spearman's rho**	0.525***
	df	54
	p-value	<.001

Note. ** p < .05, ** p < .01, *** p < .001*

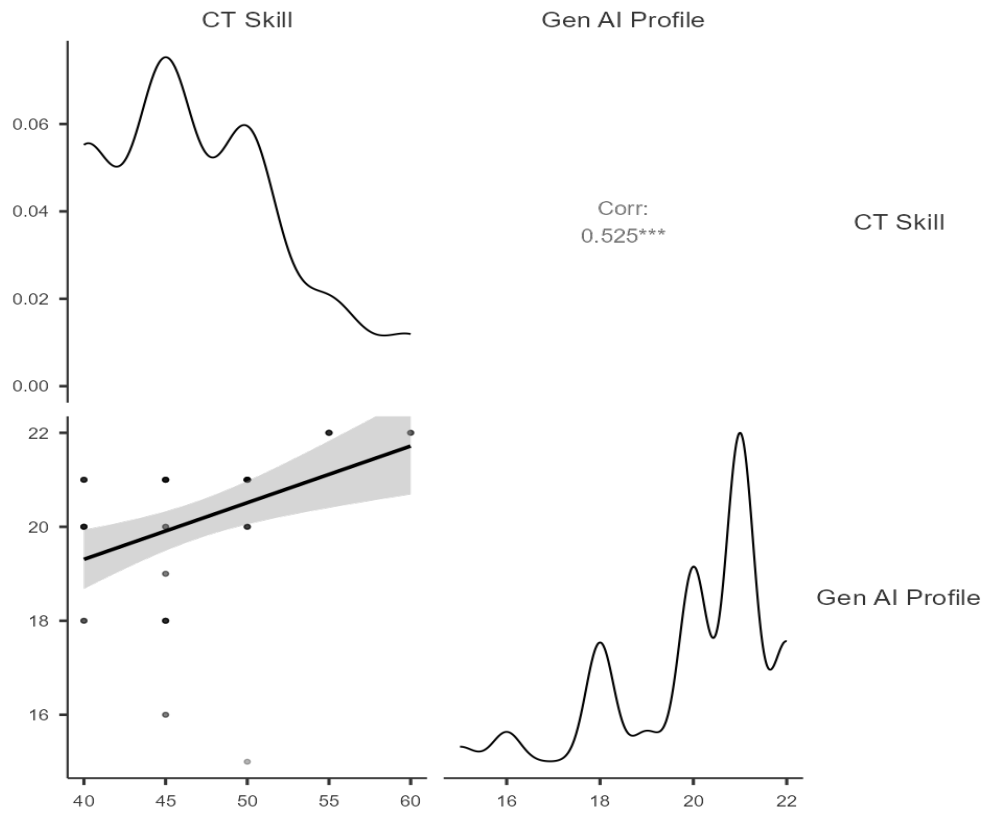

Figure 2. Correlation matrix and density plot

Figure 2 displays the relationship between the AI Gen Usage Profile and students' CT Skills. The regression line is positive, meaning that the higher the AI Gen Profile score (meaning good AI Gen usage), the higher the CT Skills. A Spearman correlation coefficient of 0.525, with a significant p-value, indicates that the relationship between the two variables is moderate and statistically significant. The shaded area around the regression line indicates the confidence interval, and the data obtained showed relatively stable variation without extreme deviations. These results support the hypothesis that wise AI Gen mastery contributes to improved CT Skills. However, the moderate strength of the relationship suggests that other influencing variables exist beyond those studied.

Discussion

RQ1 Profile of Gena AI Usage in Physics Learning

A medium level of use dominates the profile of Gen AI use among students during physics learning. This level of usage indicates that students have mastered using Gen AI to support their physics learning activities. However, students tend to quickly accept answers from Gen AI without conducting an in-depth investigation or double-checking. Students' tendency not to check Gen AI answers is thought to depend on their understanding of the science content. It has been reported that elementary school students struggled to assess the correctness of Gen AI answers regarding the scientific concept of light (Kang & Park, 2024). This inability to identify these errors led students to accept Gen AI answers without question (Gervacio, 2024).

Meanwhile, when comparing students with low and high usage, students with a low usage profile were more dominant. Students with low levels of Gen AI usage tended to be passive and accept any response. They made no effort to question, check, or compare Gen AI answers. They tended to view Gen AI responses as the only correct answer (Pitts

et al., 2026). Students with this usage pattern require special attention, as it indirectly violates academic ethics and integrity (Zhai et al., 2024). Furthermore, over-reliance on Gen AI for problem-solving decisions can lead to "cognitive atrophy," where students lose the ability to think independently (Karamuk, 2025). Therefore, checking and evaluating AI answers is essential to maintain critical thinking skills.

RQ2 Differences in CT Skills based on Gen AI Usage Levels

This study measured students' critical thinking skills in the context of physics. A Kruskal-Walls test revealed differences in critical thinking skills among students with low, medium, and high levels of Gen AI use. The effect size ε^2 of 0.410 indicates that students' Gen AI usage profiles significantly influence critical thinking skills. However, the magnitude of this effect size needs to be considered, given the relatively small sample size. However, these findings can still be interpreted in a limited way.

Differences in thinking skills across groups were further analyzed using post hoc tests in Table 5. The post hoc test results showed significant differences in critical thinking skills between the medium and high groups, and between the low and high groups. Meanwhile, there was no significant difference in critical thinking skills between the medium and low groups. These findings support the idea that students' appropriate use of Gen AI can train critical thinking skills (Zhang & Liu, 2025). Students who think critically will be able to evaluate Gen AI results, identify bias, and judge the validity of information (Rusandi et al., 2023). These activities demonstrate a pattern of Gen AI use in the High category.

RQ3 Correlation between Gen AI Usage and CT Skills

To determine how these two variables correlate, namely the profile of Gen AI usage and critical thinking skills in physics, a Spearman correlation test was conducted. Based on the correlation test results in Table 6, the two variables were positively correlated at 0.525. This value falls within the moderate correlation category. This finding suggests that better, more ethical use of Gen AI by students indicates that those students also possess high levels of critical thinking skills. This finding supports previous research showing a positive correlation between the use of Gen AI and academic integrity and students' critical thinking skills (Alkam et al., 2026). However, other aspects of critical thinking skills could not be measured in this study. There is still potential to explore the variables that influence and mediate critical thinking skills.

This research contributes to the findings, demonstrating that the presence of GenAI technology does not necessarily weaken students' critical thinking skills. The findings demonstrate that ethical and responsible use of GenAI is positively correlated with critical thinking skills. In the context of physics learning, strong mastery of science content is necessary for students to identify, evaluate, and assess the accuracy of Gen AI answers (Kang & Park, 2024). Therefore, it is strongly recommended not to use general-purpose Gen AI models in learning. Adapting Gen AI according to its intended use (in this case, learning) is essential to align with the user's needs and context (Lee et al., 2026). Specific and proper design can mitigate academic dishonesty, over-reliance, and misinformation (Tang et al., 2025). Teacher supervision and ethical safeguards are essential to ensure responsible use and maintain academic integrity. Students still feel the need for teacher guidance to overcome their limited understanding and abilities in science content and AI (Kilde-Westberg et al., 2025). This discussion focuses on the need for collaboration among teachers, researchers, and instructional design developers to design Gen AI-based physics learning that aligns with the desired pedagogical goals.

CONCLUSION

Fundamental Finding: Based on this study's findings, students are still predominantly quick to accept Gen AI's answers during physics learning. Only a small number of students are accustomed to doubting, checking, and evaluating answers from Gen AI. There is a significant difference in critical thinking skills between students who use Gen AI ethically and those who readily accept Gen AI's answers. The ethical and responsible use of Gen AI is positively correlated with students' critical thinking skills in physics learning. **Implication:** The design and use of Gen AI in physics learning must be directed contextually and ethically, and structured under teacher supervision, to encourage reflective use and optimize the development of students' critical thinking skills. **Limitation:** This study is limited to a relatively small number of samples and non-parametric data analysis, so the generalizability of the results needs to be carefully considered. **Future Research:** Other variables that influence critical thinking skills still need to be explored, including variables that act as mediators.

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Aminudin Zakaria
Postgraduate Programe of Science Education,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya, East Java, 60213, Indonesia
Email: 25030795021@mhs.unesa.ac.id

Budi Jatmiko
Department of Physics Education, Faculty of Mathematics and Natural Sciences
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya, East Java, 60213, Indonesia
Email: budijatmiko@unesa.ac.id

***Binar Kurnia Prahani (Corresponding Author)**
Department of Physics Education, Faculty of Mathematics and Natural Sciences
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya, East Java, 60213, Indonesia
Email: binarprahani@unesa.ac.id

Cahyo Febri Wijaksono
Universität für Weiterbildung Krems
Dr.-Karl-Dorrek-Straße 30, 3500 Krems an der Donau, Austria
Email: cahyofebri06@gmail.com