



The Paradox of AI Integration in Basic Science Project-Based Learning: Comparing Perceived Effectiveness and Actual Product Quality

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Abstract: This study investigates the impact of Artificial Intelligence (AI) integration in Project-Based Learning (PjBL) within a Basic Science Concepts course, specifically focusing on the paradox between student perceptions and actual learning performance. A quantitative comparative design was employed, involving pre-service teachers divided into AI-reliant and non-AI groups. Data were collected through Likert-scale questionnaires and project product assessment rubrics, then analyzed using the Mann-Whitney U test. The results reveal a significant disparity: while the AI group reported significantly higher perceptions of learning effectiveness and teamwork satisfaction, their actual product quality and conceptual depth in science were lower than those of the non-AI group. This suggests that AI integration may create an illusion of competence, where ease of information access reduces the depth of critical inquiry and collaborative synthesis. The study concludes that AI should function as a guided cognitive tool rather than a primary source in science education. These findings offer critical implications for educators to design AI-integrated PjBL that prioritizes conceptual understanding over technological convenience.

Keywords: Artificial intelligence; Learning outcomes; Project-based learning; Science education; Student perception

Introduction

Artificial Intelligence (AI) has brought rapid transformation across various sectors, including education, by providing innovative tools to enhance learning experiences. The integration of AI in higher education enables personalized learning, real-time feedback, adaptive assessment, and increased student engagement (Holmes et al., 2022; Chen et al., 2020). Recent advances indicate that AI can facilitate the development of 21st-century skills, such as problem-solving, critical thinking, collaboration, and creativity (Zawacki-Richter et al., 2019). In particular, the transformation of collaborative PjBL is considered essential to navigate the complex educational demands of the Society 5.0 era (Arian et al., 2025; Guo et al., 2020). One of the most effective pedagogical approaches for

fostering these skills is Project-Based Learning (PjBL). Empirical evidence consistently demonstrates that the structured application of PjBL models, including innovative integrations with deep learning frameworks and ethnoscience modules, significantly enhances students' motivation, collaboration, scientific reasoning, critical and creative thinking abilities, as well as the overall pedagogical competence of pre-service teachers (Yanti et al., 2023; Nasharuddin et al., 2025; Akbar et al., 2025; Taufik et al., 2025).

By integrating AI with PjBL, students are expected not only to acquire theoretical knowledge but also to apply it in practical and collaborative contexts. The rapidly growing integration of Artificial Intelligence (AI) in science education offers transformative potential, functioning as a multifaceted tool that simplifies complex abstract concepts, serves as a machine-

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learning-based teacher assistant to diagnose misconceptions, and utilizes generative models like ChatGPT to facilitate interactive future learning environments for both teachers and students (Purnama et al., 2025; Ayuni et al., 2024; Arini et al., 2025; Purnama et al., 2023; Saragih et al., 2023). However, the implementation of AI in higher education, particularly in developing countries such as Indonesia, continues to face several challenges, including limited digital literacy, ethical concerns, infrastructure readiness, and pedagogical adaptation. Sperling et al. further emphasize that although AI literacy has rapidly emerged as a prominent topic in educational research, it remains largely underexplored within teacher education contexts and has not yet been sufficiently grounded in teachers' professional knowledge (Sperling et al., 2024).

Kim and Cho found that students expect AI to play multiple roles, such as a learning companion, tutor, and an effective tool for completing tasks during student-AI collaboration (Student-AI Collaboration, SAC). Their findings indicate that SAC provides benefits in both the affective domain and task performance. However, students also highlighted several challenges arising from limitations of AI as well as from the students themselves. These findings offer insights into the dynamics of student-AI interaction in problem-solving and meaningful learning, while also implying the need to advance AI literacy and to design pedagogically richer AI-supported learning environments to enhance the effectiveness of student-AI collaboration (Kim & Cho, 2025; Anders & Dux Speltz, 2025).

Boubker (2024) and Kasneci et al. (2023) conducted a study that extends the understanding of how ChatGPT influences students' learning processes by examining the factors that facilitate its use. The empirical findings confirm that output quality has a positive effect on perceived usefulness, actual use of ChatGPT, and student satisfaction. In addition, social influence was found to be a significant contributor to perceived usefulness and the use of ChatGPT. The study involved higher education students in Morocco, with data collected through an online questionnaire using a convenience sampling method and analyzed using Partial Least Squares (PLS) techniques. The results further indicate that perceived ease of use significantly affects perceived usefulness and student satisfaction. Moreover, perceived usefulness of ChatGPT positively influences its level of use and student satisfaction, which in turn enhances individual impact. These findings provide strategic recommendations for higher education administrators to update teaching practices in the digital era in order to maximize the potential of artificial intelligence in improving student learning outcomes (Long & Magerko, 2020; Roll & Wylie, 2016).

Zheng et al. (2024) and Wang et al. (2024) highlight emerging challenges arising from the increasing use of Artificial Intelligence (AI) by students in the context of Project-Based Learning (PBL). This study employs a co-design approach to explore the potential of student AI usage data as a novel source of information for PBL assessment. The researchers conducted workshops with 18 university students, in which participants were invited to envision alternative scenarios that allowed them to freely use AI in PBL while simultaneously reporting their AI usage processes as part of the assessment of their skills and contributions. The workshop outcomes generated a variety of AI use scenarios in PBL, as well as analytical approaches that reflect students' perspectives on the transformation of educational goals in the AI era. The study also found that students with differing attitudes toward AI demonstrated distinct preferences in how they analyzed and understood their own AI use. Based on these findings, Zheng et al. discuss future research opportunities related to student-AI interaction and the need for a deeper understanding of AI-enhanced learning (Zhai et al., 2021; Zhang & Aslan, 2021).

The integration of generative artificial intelligence (AI) into Project-Based Learning (PBL) is presented as an approach with the potential to revolutionize teaching in the field of business education. This chapter begins by outlining the core concepts of PBL and emphasizing how this model supports the development of students' critical thinking, creativity, and problem-solving skills. It then explains how generative AI technologies, such as simulations and predictive models can enhance learning objectives by providing students with access to real-world business scenarios (Ruark & Biazzin, 2025). The integration of AI-based solutions makes business education more dynamic and adaptive, enabling more personalized learning experiences for students. The case studies presented demonstrate the effective application of AI in improving student engagement and learning outcomes, while also addressing implementation challenges, including infrastructure requirements, educator training needs, ethical dilemmas, and data privacy issues (Tariq, 2025). In addition, AI literacy has been shown to directly influence perceptions of AI use for social good, self-efficacy in learning AI, and awareness of AI ethics, while indirectly shaping behavioral intentions to learn AI (Du et al., 2024; Guo et al., 2020).

Merino-Campos (2025) explains that artificial intelligence (AI)-based solutions have significant potential to enhance personalized learning in higher education. The use of AI can improve learning efficiency, tailor instructional content, and streamline administrative processes, thereby fostering greater student engagement and improved academic

performance. However, the implementation of this technology also presents several challenges, including ethical concerns, data privacy issues, and the need for adequate training and support for educators. According to Merino-Campos, existing research in this area remains diverse in terms of methodologies and reporting practices, highlighting the need for more standardized evaluation frameworks and longitudinal studies to better understand the long-term impacts and sustainability of AI use in education (Zawacki-Richter et al., 2019). The author emphasizes that for AI's potential to be fully realized, its implementation must be balanced by carefully considering both opportunities and limitations. Collaboration among educators, policymakers, and higher education administrators is therefore essential to ensure the ethical, contextually relevant, and pedagogically enriching integration of AI in higher education (Cotton et al., 2024; Bardach et al., 2021).

While Artificial Intelligence (AI) offers efficiency in sourcing references and constructing arguments, concerns have emerged regarding the degradation of conceptual depth when students rely on AI as their sole information source. This 'AI dependency' phenomenon potentially hinders the critical thinking process, which should be the core of Project-Based Learning (PjBL). Most prior studies have predominantly focused on the positive potential of AI in enhancing student engagement. Thus, without being fully recognized, an emerging hidden threat continues to develop: dependence on AI. When students use AI not merely as a collaborative tool but as their sole source of information, their conceptual depth may significantly decline. In the context of Project-Based Learning (PjBL), where critical thinking and authentic problem-solving are fundamental, such dependence can be particularly problematic. This reliance risks producing learning artifacts that appear well-developed on the surface but lack genuine academic rigor.

Investigating this phenomenon is particularly important, especially for pre-service teachers. If future educators fail to develop deep conceptual understanding due to excessive reliance on AI, the long-term consequences for the quality of education could be detrimental. Therefore, it is crucial to move beyond merely evaluating the technical capabilities of AI and begin carefully examining the actual quality of the pedagogical outputs produced by students who use AI assistance.

Accordingly, this study aims to address this critical gap by exploring pre-service teachers' perceptions and their actual performance in the Basic Science Concepts course at Universitas Muslim Nusantara Al-Washliyah. This research specifically focuses on how AI supports active learning, the effectiveness of teamwork, and its

impact on learning outcomes, while also evaluating the quality of the project products produced by students. By employing a comparative quantitative design, this study shifts the focus from merely examining the technical capabilities of AI to investigating students' direct learning experiences and the quality of the artifacts produced by pre-service teachers.

The novelty of this study lies in uncovering a pedagogical paradox: a significant discrepancy between students' high perceived learning success when using AI and the measurable decline in the conceptual quality of their PjBL products. Ultimately, the findings of this study are expected to provide crucial empirical evidence and strategic insights for educators and policymakers in designing adaptive and pedagogically safe AI-integrated curricula to mitigate the risks of AI dependency in higher education institutions.

Method

Research Design

This study employed a quantitative approach with a comparative design to obtain empirical insights into the use of Artificial Intelligence (AI) in Project-Based Learning (PjBL). This design was specifically selected to examine the AI Paradox by contrastively comparing two distinct groups: an experimental group that utilized AI as their primary source of information, and a control group that followed a conventional PjBL process without AI support. The research was conducted in sequential stages. First, following a preliminary literature review, students participated in their respective PjBL environments. Second, data were collected by assessing students' perceptions of learning effectiveness and teamwork through Likert-scale questionnaires. Third, their actual project performance and conceptual depth were objectively evaluated using standardized assessment rubrics. Finally, the collected data were statistically analyzed using the Mann-Whitney U test and Cliff's δ to measure the discrepancy between the perceived ease of learning and the actual quality of the learning outcomes. The systematic flow of the research procedure is illustrated in Figure 1.

Participants

The participants in this study consisted of a total population of 58 undergraduate students (N=58) from the Primary School Teacher Education (PGSD) program enrolled in the Basic Science Concepts course at Universitas Muslim Nusantara Al-Washliyah. A total population sampling technique was employed to ensure the highest representativeness within this specific academic context, involving all students enrolled in the course during the current semester. Participants were divided into two intensive treatment groups: the AI-

dependency group (n=29), which utilized AI as their primary cognitive partner, and the Non-AI group (n=29), which engaged in conventional collaborative inquiry. Although the sample size is localized, it provides sufficient statistical power for non-parametric analysis (Mann-Whitney U) and allows for a controlled, in-depth comparison of how AI dependency directly impacts the quality of science project artifacts.

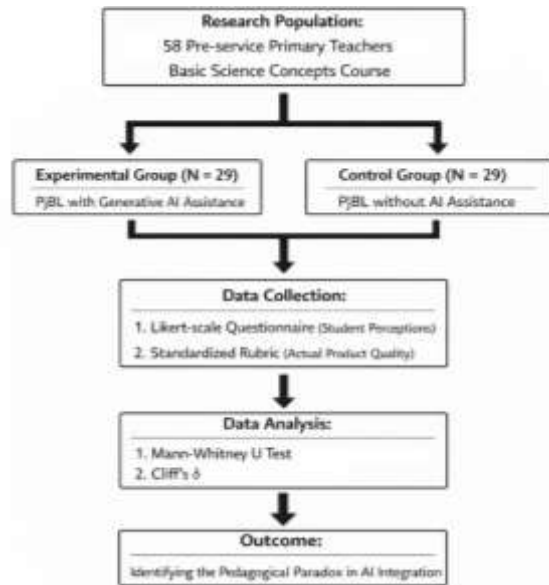


Figure 1. Research design flowchart

Data Collection

Data were collected from two primary sources to statistically compare the perceived versus actual impact of AI in PjBL. The first data source was a quantitative questionnaire using a five-point Likert scale. The measured aspects included: learning support, teamwork effectiveness, learning outcomes, challenges of AI use, and sustainability of AI use (Ouyang & Jiao, 2021). This questionnaire was administered to both groups (AI and Non-AI) to identify significant differences in their learning experiences.

The second and most crucial data source was the objective assessment of students' project products. All project products were evaluated using an analytical scoring rubric to measure the Accuracy and Depth of Scientific Concepts, Application of Concepts in the Project, Product Quality, Group Work Process and Collaboration, and Presentation and Communication of Project Results. By comparing these objective scores with the subjective questionnaire data, this study was able to identify whether the high perceived effectiveness in the AI group aligned with the actual quality of the products or if a paradox existed. This dual-source quantitative approach enabled data triangulation between subjective perceptions and objective performance metrics.

Instrument Validity and Reliability

Instrument validity was examined using the Pearson Product-Moment correlation at a 5% significance level, with an r-table value of 0.254 (N=58). An item was considered valid if the calculated correlation coefficient (r-count) was greater than the r-table value and the significance value (Sig. 2-tailed) was less than 0.05. The results indicated that most items showed positive and significant correlations and were therefore considered valid. However, five items (P31, P32, P34, P35, and P36) did not meet the validity criteria because their r-count values were lower than the r-table value and/or their significance values exceeded 0.05. Consequently, these items were excluded from further analysis.

Subsequently, reliability analysis was conducted on the validated instrument to assess the internal consistency of each measurement aspect. The results demonstrated that all aspects of the instrument exhibited excellent internal consistency, with Cronbach's alpha coefficients ranging from 0.869 to 0.941. Specifically, the alpha values were 0.895 for Learning Support, 0.941 for Teamwork Effectiveness, 0.936 for Learning Outcomes, 0.869 for Challenges of AI Use, and 0.938 for the Sustainability of AI Use. All coefficients exceeded the commonly accepted minimum threshold ($\alpha > 0.70$), indicating that the instrument was reliable and appropriate for further analysis. Overall, the instrument was found to be of high quality, valid, and appropriate for measuring students' perceptions of AI implementation in project-based learning, particularly within the context of pre-service elementary teacher education.

Data Analysis

Data were analyzed using the non-parametric Mann-Whitney U test to determine whether significant differences existed between the AI and Non-AI groups. This statistical test was selected due to the non-normal distribution of the data. The analysis specifically focused on identifying the AI Paradox, where a group might report significantly higher perception scores while demonstrating significantly lower actual product quality (science conceptual depth) compared to the control group. Overall, this analytical framework was designed to provide a strong quantitative basis for evaluating the pedagogical risks of AI dependency in science education.

Result and Discussion

Result

Prior to conducting the group comparison analysis, the data were first tested for normality using the Shapiro-Wilk test. The results indicated that most

variables did not meet the assumption of normal distribution in both the AI and non-AI groups. In the group of students who used AI, the score distributions for all measured aspects namely active learning support, teamwork, learning outcomes, challenges in using AI, and sustainability of AI use showed deviations from normality ($p < 0.001$).

In contrast, for the group of students who did not use AI, the score distributions for teamwork, learning outcomes, and sustainability of AI use also violated the normality assumption ($p < 0.001$), whereas the

distributions for active learning support ($p = 0.107$) and challenges in using AI ($p = 0.564$) met the normality assumption.

Based on these results, it can be concluded that the assumption of normality was not consistently satisfied across both groups. Therefore, group differences were analyzed using the non-parametric Mann-Whitney U test, which is more appropriate for comparing two independent groups with non-normally distributed data.

Table 1. Mann-Whitney U Test Results for Student Perceptions in AI and Non-AI Groups

Dimension	U	p	Mean AI	Mean Non-AI	Cliff's δ
Learning support	475	0.36	4.13	4.03	0.13
Teamwork effectiveness	608.5	0.00	4.11	3.85	0.45
Learning outcomes	536	0.03	4.07	3.89	0.28
Challenges of AI use	728,5	0.00	4.00	3.32	0.73
Sustainability of AI use	608	0.00	4.08	3.87	0.45

Descriptively, students in both the group completing projects with the assistance of artificial intelligence and the group completing projects without artificial intelligence demonstrated relatively positive perceptions of project-based learning. The mean scores across all measured aspects ranged from 3.3 to 4.1 on a five-point Likert scale.

Regarding support for active learning, the analysis indicated no significant difference between the two groups ($U = 475$; $p = 0.375$). Although the mean score of the AI group ($M = 4.13$) was slightly higher than that of the Non-AI group ($M = 4.03$), the difference was not statistically significant. This finding suggests that the use of AI did not substantially differentiate students' perceptions of active learning support.

In contrast, a significant difference was found in the teamwork aspect between the AI and Non-AI groups ($U = 608.5$; $p = 0.001$). The AI group obtained a higher mean score ($M = 4.11$) compared to the Non-AI group ($M = 3.85$). This result indicates that the use of AI in project-based learning is associated with more positive perceptions of teamwork.

A significant difference was also observed in the learning outcomes aspect ($U = 536$; $p = 0.032$). The mean score of the AI group ($M = 4.07$) was higher than that of the Non-AI group ($M = 3.89$), indicating that students who used AI tended to perceive their learning outcomes more positively.

For the challenges of AI use, the results showed a significant difference between the two groups ($U = 728.5$; $p = 0.001$). The AI group reported a higher mean score ($M = 4.00$) than the Non-AI group ($M = 3.32$). This finding indicates that students who used AI perceived the challenges of using the technology more strongly during the learning process.

Finally, a significant difference was found in the sustainability of AI use ($U = 608$; $p = 0.001$). The AI group obtained a higher mean score ($M = 4.08$) compared to the Non-AI group ($M = 3.87$), suggesting a stronger tendency among students to continue using AI in future learning activities.

Table 2. Average Scores of Project Product Assessment for Non-AI and AI Groups

Assessment	Non AI	AI
Accuracy and depth of scientific concepts	3.00	3.00
Application of concepts in the project	2.75	3.00
Product quality	3.25	2.75
Group work process and collaboration	3.50	3.25
Presentation and communication of project results	3.00	3.00

Note: Scores represent the average of four groups in each category (scale 1-4)

The results of the project product assessment indicate that the average scores across all assessed aspects ranged from 2.75 to 3.50 on a 1-4 scale. In terms of the application of concepts to the product or project, the AI-assisted groups achieved a higher average score ($M = 3.00$) compared to the non-AI groups ($M = 2.75$).

Conversely, for the quality of the product or project artefact, the non-AI groups obtained a higher average score ($M = 3.25$) than the AI-assisted groups ($M = 2.75$). A similar pattern was observed in the aspect of group work processes and collaboration, where the non-AI groups recorded an average score of 3.50, while the AI-assisted groups achieved an average score of 3.25.

Meanwhile, for the accuracy and depth of science concepts as well as the presentation and communication of project outcomes, both groups demonstrated identical average scores, each with a mean of 3.00.

Discussion

The findings of this study indicate that the integration of Artificial Intelligence (AI) in project-based learning does not automatically produce uniform effects across all aspects of learning. In general, students in both groups demonstrated positive perceptions of project-based learning; however, the differences observed between the AI and Non-AI groups were selective and context-dependent.

Kakhkharova et al. (2024) describe AI-based pedagogy as a transformative approach with the potential to create adaptive, personalized, and responsive learning environments. Nevertheless, the results of this study suggest that the integration of AI in Project-Based Learning (PBL) was perceived relatively positively by students in both the AI-assisted and non-AI groups. This finding indicates that PBL as a pedagogical approach inherently fosters active student engagement, while AI functions primarily as a supportive tool that enriches the learning process rather than serving as the primary determinant of instructional quality. Previous research has shown that the application of AI-assisted Project-Based Learning can significantly enhance students' critical thinking skills compared to conventional learning approaches. The integration of AI within PBL not only strengthens students' analytical and reflective abilities but also increases engagement in discussion and collaboration. The use of AI tools such as ChatGPT and Canva AI has been shown to support students in formulating problems, searching for references, and constructing arguments in a more systematic and creative manner, positioning AI-assisted PBL as an effective and innovative pedagogical approach in higher education (Bahrul Alim & Butsiarah, 2025).

In terms of support for active learning, students in the AI group obtained slightly higher mean scores than those in the Non-AI group; however, the difference was not statistically significant. This finding suggests that AI is not a primary determining factor in fostering active learning experiences but rather serves as a supplementary tool whose effectiveness depends heavily on pedagogical design. In other words, when PBL is designed in a participatory and student-centered manner, the presence of AI does not automatically enhance students' perceptions of active learning support. Although AI-based learning tools have been shown to improve cognitive knowledge and affective learning outcomes, their impact on higher-order cognitive processes remains variable and is strongly influenced by instructional design and implementation (Luo et al., 2025). The role of the teacher as a facilitator therefore remains a key factor in leveraging AI tools effectively to enhance the quality of project-based

learning, both in instructional practice and student learning outcomes (Yuna et al., 2025; Celik et al., 2022).

Conversely, the significant differences observed in the teamwork dimension indicate that AI use is associated with more effective collaborative dynamics. Students in the AI group reported more positive teamwork experiences, which may be attributed to the role of AI in supporting task coordination, role distribution, and information processing during project work. However, this finding should be interpreted with caution, as improved perceptions of teamwork do not necessarily correspond to higher-quality final products, as reflected in the project assessment results. This condition suggests that AI primarily functions as an instrumental support tool in collaborative work, while the quality of social collaboration remains dependent on interpersonal interaction dynamics among students. This interpretation aligns with studies on student-AI collaboration that emphasize the variability of AI's impact based on user characteristics and attitudes (Kim & Lee, 2023). Although the integration of artificial intelligence and machine learning in education holds considerable potential for enhancing learning quality and personalization, its application remains constrained by implementation complexity as well as ethical and social considerations that require further research and active stakeholder engagement (Tiwari, 2023).

In the learning outcomes dimension, students who used AI reported more positive perceptions compared to the Non-AI group. This finding indicates that AI has the potential to support students in understanding concepts and completing project tasks more efficiently. However, when these perceptions are examined alongside the project product assessment data, this advantage is not fully reflected in the quality of the resulting artifacts. In contrast, the Non-AI group achieved higher scores in product quality, suggesting that perceived improvements in learning outcomes do not necessarily correspond to higher performative achievement. This finding is consistent with the review by Sasikala et al. (2024), which emphasizes that the role of teachers remains irreplaceable in AI-supported learning environments. Although AI can automate various administrative tasks and provide instructional support, teachers' roles as facilitators, mentors, and socio-emotional supporters continue to be central to the learning process. Therefore, the most effective approach is to integrate AI in a complementary manner rather than as a substitute for the role of educators.

The most prominent finding of this study emerges in the dimension of challenges associated with AI use, which exhibits a large effect size. Students who used AI experienced significantly more challenges than those in the Non-AI group. This result indicates that the integration of AI in learning not only offers convenience

but also introduces cognitive load, technological adaptation demands, and potential dependency on AI systems. These findings reinforce the view that the use of AI in educational contexts requires clear pedagogical guidance to ensure that technology does not hinder deep and meaningful learning processes.

In the context of large-scale online Project-Based Learning (PjBL), students primarily use AI to support technical tasks, information searching, and content creation during the planning and implementation stages of projects (Ou & Joyner, 2025). Although the full impact of AI developments cannot yet be predicted with certainty, AI applications are expected to become a major issue in educational technology over the next two decades. AI-based tools and services have significant potential to support students, lecturers, and administrators throughout the student lifecycle through adaptive and personalized learning support systems. This is particularly relevant for large-scale higher education institutions, including open universities and distance education providers, as Artificial Intelligence in Education can help balance the expansion of access to higher education (mass higher education) with the provision of flexible, interactive, and personalized learning experiences, while also reducing lecturers' workload so that they can focus more on empathetic and human-centered teaching (Zawacki-Richter et al., 2019).

With regard to the sustainability of AI use, students in the AI group demonstrated a stronger tendency to continue using AI in their learning activities. This finding indicates a relatively high level of technology acceptance, albeit accompanied by perceived challenges. It suggests that students recognize the practical value of AI in supporting learning; however, the sustainability of its use needs to be accompanied by strengthened AI literacy and clearly defined boundaries for AI utilization.

The analysis of project product assessments provides an additional and important perspective. While the AI group showed an advantage in applying concepts to project products, the non-AI group outperformed in terms of product quality and collaborative processes. These findings suggest that AI primarily functions as a cognitive support tool during the early stages of idea development, whereas the final quality of the product and the depth of collaborative processes remain strongly determined by students' direct engagement. Accordingly, AI should not be positioned as a substitute for thinking and collaboration processes, but rather as a tool that needs to be integrated critically and in a controlled manner.

The findings of this study demonstrate a significant disparity between student perceptions and objective performance. Students in the AI group perceived their learning outcomes and teamwork significantly more

positively than those in the non-AI group ($p < 0.05$). This phenomenon is likely attributed to an 'illusion of ease' offered by AI in streamlining task coordination and information processing. However, project assessment data reveals a contrasting reality: the non-AI group achieved higher scores in product quality ($M=3.25$) and group work processes ($M=3.50$) compared to the AI group ($M=2.75$ and $M=3.25$, respectively).

Utilizing AI as a sole information source in the Basic Science Concepts project appeared to cause students to bypass deep literature exploration and the rigorous critical reflection typically found in manual group discussions. While AI provides instantaneous information, the content often remains generic; consequently, the final products lacked the originality and conceptual depth observed in the work of groups relying on direct human synthesis. This reinforces the notion that without rigorous pedagogical guidance, AI integration can inadvertently hinder the attainment of optimal product quality in PjBL.

Conclusion

This study reveals a significant pedagogical paradox related to the integration of Artificial Intelligence (AI) in Project-Based Learning (PjBL) within science education. The research context involved a population of 58 undergraduate students (pre-service teachers) from the Primary School Teacher Education (PGSD) program who were enrolled in the Basic Science Concepts course. Quantitatively, the findings demonstrate a contradictory gap between students' perceptions and their actual performance. In terms of teamwork, students in the AI-dependent group reported significantly higher perceived collaboration effectiveness ($M = 4.11$, $p < 0.05$) compared to the non-AI group ($M = 3.85$). However, objective performance evaluation indicated that the actual collaboration process in the AI group was rated lower ($M = 3.25$) than that of the non-AI group ($M = 3.50$). A similar contradiction was also observed in the final outcomes. While the AI group reported high perceived learning outcomes ($M = 4.07$), the actual quality of their project products was lower ($M = 2.75$) compared to the non-AI group ($M = 3.25$). Furthermore, the high level of challenges associated with AI use reported by the experimental group (Cliff's $\delta = 0.73$) suggests that the integration of this technology introduces an additional cognitive load. Limited AI literacy is strongly suspected to restrict students' ability to critically evaluate, validate, and synthesize AI-generated outputs, preventing the information obtained from being transformed into deep conceptual understanding. This limitation is ultimately reflected in the lower quality of the PjBL products produced by the AI group. As a practical implication for

lecturers and science teachers, the integration of AI within the PjBL model requires educators to design assessment rubrics that evaluate not only the final product but also the processes of critical thinking and the authenticity of students' arguments. Educators should also establish clear boundaries to ensure that AI functions solely as a complementary tool for cognitive scaffolding rather than as the primary source of information determining conceptual understanding. Nevertheless, this study has several limitations, including the relatively small sample size ($N = 58$), its restriction to a single higher education institution, and the relatively short duration of AI implementation in the learning experiment. Therefore, future research is strongly recommended to develop more effective pedagogical strategies or models for AI integration specifically designed for project-based learning environments. Studies with larger sample sizes and longitudinal designs are also necessary to explore the long-term impacts of AI use, enabling educators to design adaptive AI-integrated curricula without creating risks of dependency in the future. Furthermore, the study highlights that AI dependency introduces significant cognitive and technological challenges, including increased cognitive load and a tendency toward generic, less original learning artifacts. These findings underscore that AI in PjBL functions as a complementary process-support tool rather than a substitute for deep inquiry. For educators and curriculum developers, the results imply that AI integration must be accompanied by strict pedagogical guidance and enhanced AI literacy. This ensures that technology serves as a cognitive scaffold that strengthens, rather than hinders, the development of critical thinking and conceptual mastery in pre-service teacher education.

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Author Contributions

Conceptualization, S. N. and R. H. H.; methodology, S. N. and K. K.; validation, R. H. H., K. K., and L. A. N.; formal analysis, S. N. and L. A. N.; investigation, M. Z. T. and S. N.; resources, R. H. H. and K. K.; data curation, M. Z. T.; writing—original draft preparation, S. N.; writing—review and editing, R. H. H., K. K., and L. A. N.; visualization, M. Z. T. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare that there is no conflict of interest in this article.

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