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Effects of STEM Based Project Based Learning Assisted by Artificial Intelligence on Cognitive Learning Outcomes and Creative Thinking Skills

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Abstract

Low cognitive learning outcomes and creative thinking skills among students in science learning have been associated with instructional processes that remain dominated by conventional methods and discovery learning, resulting in suboptimal student engagement. This study aimed to examine the effect of an Artificial Intelligence (AI)-assisted, STEM-based Project-Based Learning (PjBL) model on the cognitive learning outcomes and creative thinking skills of seventh-grade students at SMPN 1 Samarinda. A quasi-experimental method with a pretest–posttest control group design was employed. Data were collected using tests of cognitive learning outcomes and creative thinking skills and were analyzed through hypothesis testing. The results showed that the experimental class achieved 100% mastery in cognitive learning outcomes, compared with 32% in the control class. Regarding creative thinking skills, the experimental class achieved 68%, while the control class achieved 22%. Hypothesis testing yielded a significance value of 0.000 < 0.05, indicating a significant effect of the AI-assisted, STEM-based PjBL model on the measured outcomes. These findings indicate that the model was effective in improving students' cognitive learning outcomes and creative thinking skills in learning about interactions among living organisms. The study contributes to the development of technology-enhanced science learning by integrating STEM and AI approaches to support more active, creative, and 21st-century skills-oriented learning.

Keywords: *Artificial Intelligence, Cognitive Learning Outcomes, Creative Thinking Skills, PjBL, Science Learning.*

I. INTRODUCTION

Education plays a strategic role in developing human resources capable of responding to the demands of the 21st century, particularly through the development of critical thinking, creativity, collaboration, and communication skills. Advances in science and technology have increasingly required learning processes to move beyond teacher-centered instruction toward approaches that actively engage students in constructing knowledge. In science education, particularly biology, students are expected not only to understand concepts theoretically but also to relate them to real-life phenomena. However, biology is often perceived as difficult because it involves numerous scientific terms, abstract concepts, and learning processes that tend to emphasize memorization rather than conceptual understanding. Meaningful biology learning should instead provide students with direct learning experiences that enable them to understand natural phenomena in a holistic and contextual manner (Syarah et al., 2021).

These conditions may contribute to low cognitive learning outcomes and underdeveloped creative thinking skills. Cognitive learning outcomes refer to students' intellectual abilities to understand, apply, analyze, evaluate, and create ideas based on the material being learned (Maria & Maulana, 2023). Creative thinking, meanwhile, refers to an individual's ability to generate new, original ideas, concepts, or solutions to address problems by integrating existing knowledge and experiences (Utomo Aji et al., 2024). Low achievement in these domains indicates that learning processes have not fully facilitated students' active exploration, problem solving, and creativity in science learning.

Initial information obtained through interviews conducted at SMP Negeri 7, SMP Negeri 24, and SMP Negeri 1 indicated that all three schools had implemented Project-Based Learning (PjBL). However, the implementation of PjBL at SMP Negeri 1 Samarinda had not yet been optimal. Some teachers continued to rely on Discovery Learning and conventional teacher-centered methods. In addition, PjBL was more frequently implemented in physics topics, whereas its application in biology learning remained limited. Consequently, student involvement in the learning process was not yet optimal, and students continued to experience difficulties in connecting biological concepts with their applications in everyday life. These conditions highlight the need for instructional innovations that can increase active student participation while simultaneously fostering higher-order thinking skills.

One instructional model considered relevant to these challenges is Project-Based Learning (PjBL). PjBL positions students at the center of learning through contextual and collaborative project-based activities. Through PjBL, students are given opportunities to explore, interpret, analyze, and synthesize information while completing authentic projects (Dewi, 2022). The model also encourages students to engage actively in authentic problem solving, collaborate in groups, make decisions, and produce innovative products. During implementation, teachers primarily serve as facilitators who guide students throughout the learning process (Anggriani et al., 2026). Kyselova (2024) found that AI-assisted PjBL could improve students' learning independence and conceptual understanding through project-based learning activities.

The potential of PjBL can be further strengthened through the integration of Science, Technology, Engineering, and Mathematics (STEM). STEM represents an integrated approach that connects concepts from science, technology, engineering, and mathematics to address real-world problems. STEM-based learning is designed to develop students' scientific and technological literacy through investigation, experimentation, product development, and contextual problem solving (Nur'Aeni et al., 2024). Its integration into learning is also consistent with the demands of 21st-century education because it encourages students to think critically, creatively, and innovatively while developing their ability to collaborate within teams.

At the same time, advances in Artificial Intelligence (AI) have created new opportunities for educational practice. AI-assisted learning can help students access information efficiently, develop ideas, analyze data, and support project completion more effectively. Nevertheless, the use of AI in science education, particularly within STEM-based PjBL, remains limited. Learning practices in many contexts continue to rely heavily on conventional methods, meaning that the potential of AI to support innovative learning has not been fully utilized. The integration of AI into project-based learning may provide additional scaffolding that helps students connect theoretical concepts with practical and contextual applications, thereby potentially supporting the development of cognitive learning outcomes and creative thinking skills.

Previous studies have reported several related but not yet fully integrated findings. Dewi et al. (2023) and Prajoko et al. (2022) reported the benefits of STEM-based PjBL for learning outcomes, conceptual understanding, and creativity, while Nur'Aeni et al. (2024), Retno et al. (2025), and Kwon and Lee (2025) emphasized the contribution of STEM-PjBL to creative thinking skills. On the other hand, Kyselova (2024) examined the implementation of AI in Project-Based Learning, but not as an integrated component of a STEM-based instructional design for the topic of interactions among living organisms. Thus, a research gap remains regarding the integration of PjBL, STEM, and AI assistance within a single instructional treatment and the simultaneous assessment of two learning outcomes: cognitive learning outcomes and creative thinking skills, including the indicators of fluency, flexibility, originality, and elaboration.

The novelty of the present study lies in integrating AI as a scaffolding component within STEM-based projects on the topic of interactions among living organisms and simultaneously assessing cognitive learning outcomes and the four dimensions of creative thinking. Based on this research gap, this study aims to analyze the effect of AI-assisted, STEM-based Project-Based Learning on the cognitive learning outcomes and creative thinking skills of seventh-grade students at SMPN 1 Samarinda.

II. METHOD

This study employed a quantitative approach using a quasi-experimental design. The quantitative approach was adopted because the data collected were numerical and analyzed using statistical procedures to determine the effect of the independent variable on the dependent variables. According to Sugiyono (2019), quantitative research is used to examine relationships between variables, particularly causal relationships involving independent and dependent variables. The research design employed was a Nonequivalent Control Group Design, a quasi-experimental design involving an experimental group and a control group. The experimental group received the instructional treatment under investigation, whereas the control group received a comparison learning treatment. Both groups were administered a pre-test and post-test to compare learning outcomes before and after the instructional process. This design was selected because the study was conducted in existing classroom settings, where random assignment of participants and complete control over experimental conditions were not possible.

The study was conducted in February 2026 during the even semester of the 2025/2026 academic year at SMPN 1 Samarinda, located at Jalan Drs. H. Anang Hasyim, Air Hitam, Samarinda Ulu District, Samarinda City, East Kalimantan 75124, Indonesia. The sample consisted of 46 seventh-grade students divided into an experimental class and a control class, with 23 students in each class. The participants were selected using purposive sampling, a non-probability sampling technique in which subjects are intentionally selected based on specific criteria relevant to the objectives of the study. Data were collected through observation and tests. Observation was conducted to obtain information regarding the implementation of the learning process and student engagement during the instructional activities. In addition, pre-tests and post-tests were administered to both groups to measure students' learning outcomes before and after the instructional process. The test instruments were developed in accordance with the research variables and objectives to obtain data on students' cognitive learning outcomes and creative thinking skills.

The research procedure began with the administration of a pre-test to both the experimental and control groups. Subsequently, each group participated in the learning process according to the predetermined treatment. The experimental group received instruction using Artificial Intelligence (AI)-assisted, STEM-based Project-Based Learning (PjBL), whereas the control group received the comparison learning treatment. After the learning process was completed, both groups were administered a post-test. The pre-test and post-test data were then collected to examine changes in learning outcomes across the two groups. The collected data were subsequently analyzed using statistical procedures to examine the effect of the instructional model on students' cognitive learning outcomes and creative thinking skills. The analysis was conducted by comparing the outcomes of the experimental and control groups based on the pre-test and post-test data.

III. RESULTS AND DISCUSSION

A. Results

Student learning mastery was analyzed based on the pre-test and post-test scores using a Minimum Mastery Criterion (KKM) of 75 as the mastery threshold. Students were considered to have achieved mastery when their scores exceeded 75. All students completed both the pre-test and post-test, each consisting of 10 essay questions. The learning outcomes examined in this section focused on students' cognitive abilities. The post-test was administered after students had completed the learning material at the end of the instructional process. The mastery data for cognitive learning outcomes in the experimental and control classes are presented in Table 1.

Table 1. Cognitive Learning Mastery in the Experimental and Control Classes

Test Type	Students Achieving Mastery	Percentage of Students	Students Not Achieving Mastery	Percentage of Students
Pre-test Control	0	0%	23	100%
Post-test Control	6	32%	17	68%
Pre-test Experimental	0	0%	23	100%
Post-test Experimental	23	100%	0	0%

As shown in Table 1, none of the students in either group achieved mastery at the *pre-test* stage. In the experimental class, all 23 students (100%) were below the mastery criterion at pre-test. Following the instructional intervention, all 23 students (100%) achieved mastery in the *post-test*. In the control class, meanwhile, 6 students (32%) achieved mastery in the *post-test*, whereas 17 students (68%) remained below the mastery criterion. The difference in mastery rates indicates that the improvement in cognitive learning outcomes was greater in the experimental class than in the control class. Descriptively, the 100% mastery rate in the experimental class, compared with 32% in the control class, indicates a difference in learning outcomes following the instructional process. This finding provides an initial indication that the instructional treatment implemented in the experimental class may have contributed positively to students' cognitive learning outcomes. However, conclusions regarding the effect of the treatment should be supported by the results of inferential statistical testing.

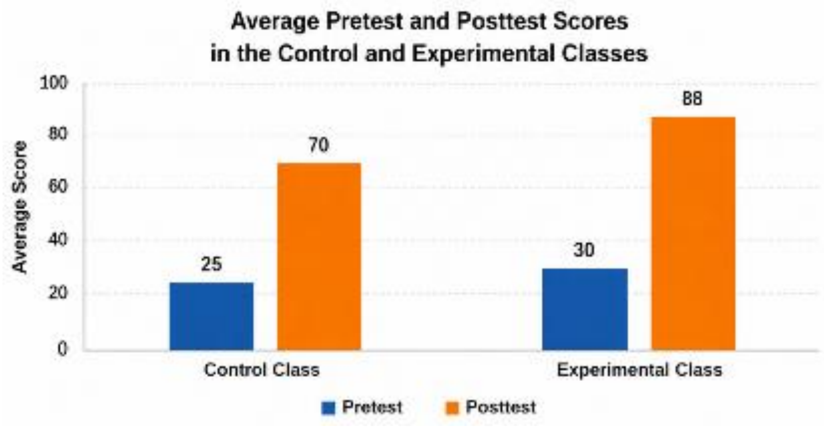

Figure 1. Mean Scores of Students' Cognitive Learning Outcomes in the Control and Experimental Classes

Based on the data analysis presented in Figure 1, the mean cognitive learning outcome score of students in the control class increased from 26.26 in the *pretest* to 69.26 in the *posttest*. Meanwhile, the experimental class showed a greater increase, with the mean score rising from 30.34 in the *pretest* to 88.47 in the *posttest*. Thus, both classes demonstrated improvements in students' cognitive learning outcomes following the instructional process; however, the increase in the experimental class was greater than that observed in the control class.

Students' mastery of creative thinking skills was determined based on their *pretest* and *posttest* scores, with mastery defined as achieving a score above the minimum mastery criterion (KKM), namely >75. The assessment consisted of 10 essay questions designed to measure students' creative thinking skills. The mastery results for the experimental and control classes are presented in Table 2.

Table 2. Students' Mastery of Creative Thinking Skills in the Experimental and Control Classes

Test	Students Achieving Mastery	Percentage of Students Achieving Mastery	Students Not Achieving Mastery	Percentage of Students Not Achieving Mastery
Control *Pretest*	0	0%	23	100%
Control *Posttest*	5	22%	18	78%
Experimental *Pretest*	0	0%	23	100%
Experimental *Posttest*	17	68%	6	32%

Table 2 shows that at the *pretest* stage, none of the students in either the control or experimental class achieved the mastery criterion for creative thinking skills. In the control class, all 23 students (100%) scored below the mastery criterion. Following the instructional process, the number of students achieving mastery increased to 5 (22%), while 18 students (78%) remained below the criterion.

A greater improvement was observed in the experimental class. At the *pretest* stage, all 23 students (100%) had not yet achieved the mastery criterion. Following the treatment, 17 students (68%) achieved mastery, whereas 6 students (32%) remained below the criterion. These findings indicate that the increase in creative thinking mastery was greater in the experimental class than in the control class. Descriptively, this result suggests that the instructional treatment implemented in the experimental class may have contributed positively to the improvement of students' creative thinking skills.

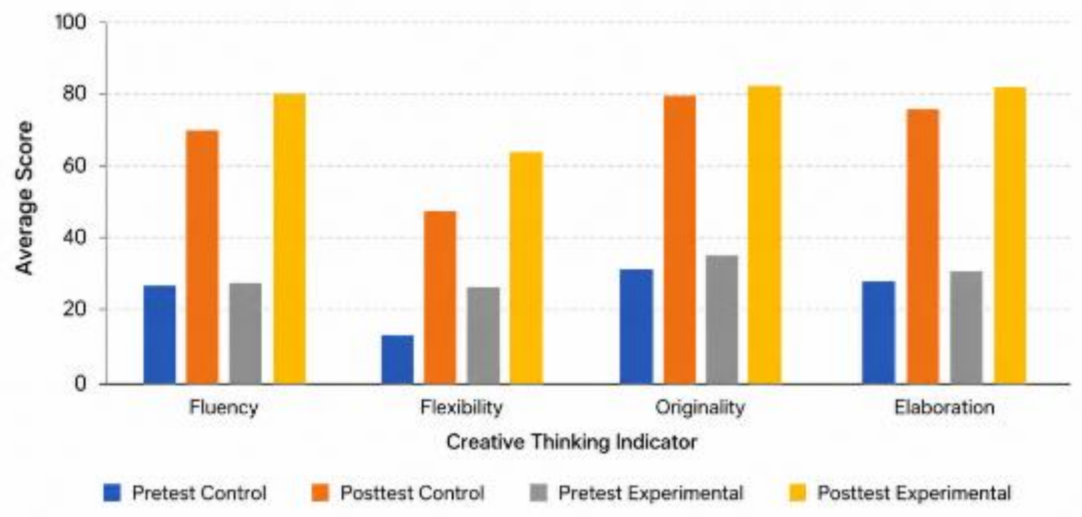

Figure 2. Comparison of the Mean Scores for Each Creative Thinking Indicator

As shown in Figure 2, the pre-test results indicate that students' creative thinking skills in the control class were relatively low across all indicators. Originality had the highest mean score (32.69), followed by elaboration (29.47), fluency (27.52), and flexibility (12.30). A relatively similar pattern was observed in the experimental class, where originality had the highest mean score (36.65), while flexibility had the lowest mean score (13.39). These initial findings indicate that students' creative thinking skills before the treatment were relatively low, particularly in terms of flexibility.

Following the instructional process, the post-test results showed improvements across all indicators in both classes. In the control class, originality had the highest mean score (79.56), followed by elaboration (77.34), fluency (71.17), and flexibility (48.52). In the experimental class, the highest mean score was observed for elaboration (82.21), followed closely by originality (81.82), fluency (80.69), and flexibility (64.91). Descriptively, both classes demonstrated improvements in creative thinking skills; however, the experimental class showed higher and more consistent post-test scores across all creative thinking indicators than the control class.

Table 3. Results of the Shapiro–Wilk Normality Test

Variable	Class/Measurement	Statistic	df	Sig.	Conclusion
Cognitive Learning Outcomes	Control *Pre-test*	.917	23	.059	Normally distributed
	Control *Post-test*	.928	23	.101	Normally distributed
	Experimental *Pre-test*	.934	23	.131	Normally distributed
	Experimental *Post-test*	.962	23	.513	Normally distributed
Creative Thinking Skills	Control *Pre-test*	.937	23	.157	Normally distributed
	Control *Post-test*	.954	23	.352	Normally distributed
	Experimental *Pre-test*	.920	23	.068	Normally distributed
	Experimental *Post-test*	.925	23	.085	Normally distributed

As presented in Table 3, the results of the *Shapiro–Wilk* normality test showed that all significance values for cognitive learning outcomes were greater than .05 for both the pre-test and post-test scores in the experimental and control classes. A similar result was obtained for creative thinking skills, for which all significance values were also greater than .05. Therefore, the data for cognitive learning outcomes and creative thinking skills in both classes met the assumption of normality.

Table 4. Results of the Homogeneity of Variance Test

Variable	Class/Measurement	Levene Statistic	df1	df2	Sig.	Conclusion
Cognitive Learning Outcomes	Control *Pre-test*	1.264	3	74	.293	Homogeneous

	Control *Post-test*	1.496	3	88	.221	Homogeneous
	Experimental *Pre-test*	1.531	3	88	.212	Homogeneous
	Experimental *Post-test*	1.264	3	88	.292	Homogeneous
Creative Thinking Skills	Control *Pre-test*	1.365	3	84	.259	Homogeneous
	Control *Post-test*	1.483	3	88	.225	Homogeneous
	Experimental *Pre-test*	1.500	3	88	.220	Homogeneous
	Experimental *Post-test*	1.365	3	88	.225	Homogeneous

As shown in Table 4, the homogeneity test results indicated that all significance values for cognitive learning outcomes were greater than .05. Similarly, all significance values for creative thinking skills exceeded .05. These results indicate that the variances of the data across the compared groups met the assumption of homogeneity.

Table 5. N-Gain Analysis of Cognitive Learning Outcomes

Data	Control Class	Experimental Class
Maximum	.77	.98
Minimum	.47	.71
Mean N-Gain	.58	.83
Category	Moderate	High

As presented in Table 5, the experimental class obtained a mean N-Gain of 0.83 for cognitive learning outcomes, which was classified as high, whereas the control class obtained a mean N-Gain of 0.58, which was classified as moderate. N-Gain scores ranged from 0.71 to 0.98 in the experimental class and from 0.47 to 0.77 in the control class. Descriptively, these results indicate a greater improvement in cognitive learning outcomes in the experimental class than in the control class.

Table 6. N-Gain Analysis of Creative Thinking Skills

Data	Control Class	Experimental Class
Maximum	.76	.81
Minimum	.40	.50
Mean N-Gain	.57	.68
Category	Moderate	Moderate

As shown in Table 6, the experimental class obtained a mean N-Gain of 0.68 for creative thinking skills, whereas the control class obtained a mean N-Gain of 0.57. Both values were classified as moderate. Although both classes fell within the same category, the experimental class descriptively demonstrated a greater improvement in creative thinking skills than the control class.

Table 7. N-Gain Analysis of the Creative Thinking Indicator: *Fluency*

Data	Control Class	Experimental Class
Maximum	.89	1.00
Minimum	.11	.49
Mean N-Gain	.59	.73
Category	Moderate	High

As presented in Table 7, the experimental class obtained a mean N-Gain of 0.73 for *fluency*, which was classified as high, whereas the control class obtained a mean N-Gain of 0.59, which was classified as moderate. Descriptively, these results indicate that the improvement in students' ability to generate ideas fluently was greater in the experimental class than in the control class.

Table 8. N-Gain Analysis of the Creative Thinking Indicator: *Flexibility*

Data	Control Class	Experimental Class
Maximum	.75	.92
Minimum	.09	.33
Mean N-Gain	.41	.59

Category	Moderate	Moderate

As shown in Table 8, the experimental class obtained a mean N-Gain of 0.59 for *flexibility*, whereas the control class obtained a mean N-Gain of 0.41. Both classes were classified as demonstrating moderate improvement. Nevertheless, the descriptive results indicate that the improvement in *flexibility* was greater in the experimental class than in the control class.

Table 9. N-Gain Analysis of the Creative Thinking Indicator: *Originality*

Data	Control Class	Experimental Class
Maximum	1.00	1.00
Minimum	.40	.40
Mean N-Gain	.70	.71
Category	High	High

As presented in Table 9, the experimental class obtained a mean N-Gain of 0.71 for *originality*, while the control class obtained a mean N-Gain of 0.70. Both classes were classified as high. The difference in mean N-Gain between the two classes was relatively small (0.01), indicating that the descriptive improvement in *originality* was nearly comparable between the experimental and control classes.

Table 10. N-Gain Analysis of the Creative Thinking Indicator: *Elaboration*

Data	Control Class	Experimental Class
Maximum	1.00	1.00
Minimum	-.48	.26
Mean N-Gain	.64	.73
Category	Moderate	High

As shown in Table 10, the experimental class obtained a mean N-Gain of 0.73 for *elaboration*, which was classified as high, whereas the control class obtained a mean N-Gain of 0.64, which was classified as moderate. The minimum N-Gain of -0.48 in the control class indicates that at least one student experienced a decrease in the *elaboration* score from pre-test to post-test. Overall, the descriptive improvement in *elaboration* was greater in the experimental class than in the control class.

B. Discussion

This study aimed to analyze the effect of Artificial Intelligence (AI)-assisted, STEM-based Project-Based Learning (PjBL) on the cognitive learning outcomes and creative thinking skills of seventh-grade students at SMPN 1 Samarinda. Overall, the findings showed that the experimental class, which received AI-assisted STEM-based PjBL, achieved higher outcomes than the control class, which was taught using Discovery Learning. These findings indicate that the integration of project-based learning, STEM, and AI can provide a more active, contextual, and problem-solving-oriented learning experience.

The hypothesis test using an independent samples t-test produced a significance value of 0.000 < 0.05, indicating a significant difference in cognitive learning outcomes between the experimental and control classes after the learning process. This finding was also supported by the N-Gain analysis. The experimental class obtained a mean N-Gain of 0.83, which was categorized as high, whereas the control class obtained a mean N-Gain of 0.58, which was categorized as moderate. Descriptively, these results indicate that the improvement in cognitive learning outcomes was greater in the experimental class than in the control class.

This improvement can be associated with the characteristics of STEM-based PjBL, which positions students at the center of learning through project activities that require them to identify problems, search for information, apply scientific concepts, develop solutions, and create products. This process allows students to construct understanding through direct learning experiences, making learning less dependent on memorization and more focused on applying concepts in real-world contexts. This finding is consistent with Dewi (2023) and Dwita and Susanah (2020), who reported that the integration of STEM into project-based learning can support improved learning outcomes and higher-order thinking skills.

The integration of STEM also enables students to connect science concepts with technology, engineering, and mathematics within a unified learning experience. Through learning by doing, students not only understand concepts theoretically but also apply them in designing and completing projects. Such experiences may strengthen conceptual understanding because students are given opportunities to connect new information with the experiences they gain during project activities.

AI support serves as an additional component that may strengthen this learning process. In instructional activities, AI can assist students in obtaining information, developing ideas, analyzing information, and receiving feedback while completing projects. In this way, AI can function as a form of scaffolding that supports students when they encounter difficulties in understanding concepts or developing solutions. This use of AI may make learning more responsive to students' needs, although its benefits remain dependent on how it is incorporated into the instructional design and guided by the teacher.

The implementation of AI-assisted STEM-based PjBL also involved students in developing products, such as instructional videos. These activities provided opportunities for students to discuss, collaborate, organize information, and communicate their understanding through tangible products. Active engagement in planning and developing projects may deepen students' understanding of the topic of interactions among living organisms because the concepts being learned are directly applied in completing the assigned tasks. Meanwhile, the control class taught using Discovery Learning also showed improvement in cognitive learning outcomes, although the improvement remained in the moderate category. This indicates that Discovery Learning still contributed to students' learning. However, within the context of this study, learning activities in the control class did not provide the same level of project integration, interdisciplinary collaboration, and technological support as those experienced by the experimental class. Therefore, differences in the characteristics of the learning experiences between the two classes may partly explain the differences in learning outcomes.

In addition to instructional factors, students' learning outcomes may also be influenced by internal factors such as motivation, interest, prior ability, and engagement during learning. Students with higher motivation and engagement are generally more likely to participate actively in project activities, search for information, and solve problems. Therefore, the improvement observed in the experimental class should be understood as the result of interactions among the characteristics of the instructional model, AI support, and individual student conditions. The findings also showed that the implementation of AI-assisted STEM-based PjBL was associated with improvements in students' creative thinking skills. The independent samples t-test yielded a significance value of $0.000 < 0.05$, indicating a significant difference between the experimental and control classes. This result was supported by the mean N-Gain scores for creative thinking skills, which were 0.68 for the experimental class and 0.57 for the control class. Although both values were categorized as moderate, the experimental class demonstrated a higher descriptive improvement.

This finding is consistent with Retno et al. (2025) and Kwon and Lee (2025), who reported that STEM-based PjBL can support the development of creative thinking through idea exploration, problem solving, and solution development. In PjBL, students are confronted with problems that do not necessarily have a single correct answer. Such conditions provide opportunities for students to generate alternative ideas, evaluate various possible solutions, and develop products based on their own thinking processes. When examined by creative thinking indicator, the pattern of improvement provides a more specific picture. For fluency, the experimental class obtained a mean N-Gain of 0.73, categorized as high, whereas the control class obtained 0.59, categorized as moderate. These results indicate that students in the experimental class experienced greater improvement in their ability to generate multiple ideas. This finding is consistent with Sutiono et al. (2024), who explained that AI-assisted STEM-PjBL activities can provide students with opportunities to explore multiple alternative solutions when addressing problems.

For flexibility, the experimental class obtained a mean N-Gain of 0.59, while the control class obtained 0.41. Both values were categorized as moderate, although the experimental class achieved a higher score. This finding suggests that learning in the experimental class provided greater opportunities for students to consider problems from different perspectives. The integration of multiple disciplines within STEM, combined with access to information through AI, may broaden the range of approaches students use to solve problems.

For originality, both groups showed high improvement, with N-Gain values of 0.71 in the experimental class and 0.70 in the control class. The difference of 0.01 indicates that the descriptive improvement in originality was nearly equivalent across the two groups. Therefore, this result should be interpreted cautiously and should not be used to claim a substantial advantage for the experimental class in terms of originality. Nevertheless, the high scores in both groups indicate that both instructional approaches provided students with opportunities to generate relatively unique ideas. Retno et al. (2025) also emphasized that STEM-based PjBL can provide space for students to develop original solutions through project activities. For elaboration, the experimental class obtained a mean N-Gain of 0.73, categorized as high, whereas the control class obtained 0.64, categorized as moderate. This finding indicates greater improvement in students' ability to develop, expand, and clarify ideas in the experimental class. It is consistent with Prajoko et al. (2022), who showed that project-based and STEM learning can encourage students to elaborate ideas more systematically through the processes of planning, developing, and refining products.

The improvement in creative thinking skills can be explained by the characteristics of STEM-based PjBL, which provide opportunities for students to become actively involved at every stage of learning, from identifying problems and searching for and processing information to designing solutions and developing products. STEM integration allows students to combine concepts across disciplines, while AI can expand access to information and alternative ideas. Together, these components may create learning conditions that encourage exploration, reflection, and the development of more flexible solutions.

Project activities such as developing instructional videos also provide opportunities for students to express ideas visually and creatively. During this process, students are required to select information, organize the presentation, develop visual concepts, and collaborate with group members. Such activities not only create a contextual learning experience but also simultaneously involve communication, collaboration, and creativity. In contrast, the control class showed relatively lower improvement in several creative thinking indicators. Learning activities that focused more heavily on reading materials, completing worksheets, and discovering concepts through relatively limited activities may have provided fewer opportunities for students to develop and test alternative ideas. This is consistent with Prabowo (2021), who stated that learning dominated by written tasks may result in more limited student engagement.

Students' creative thinking skills are also not determined solely by the instructional model. Internal factors such as motivation, interest, cognitive readiness, and self-confidence, as well as external factors such as teacher roles, the learning environment, and technological support, may influence learning success. Muderawan (2019) explained that psychological, social, and environmental factors contribute to students' learning processes and outcomes. Therefore, differences in creative thinking achievement in this study should be understood as the result of interactions between the instructional design, student characteristics, and the learning environment.

Overall, the findings indicate that AI-assisted STEM-based PjBL was associated with higher cognitive learning outcomes and creative thinking skills than Discovery Learning within the context of this study. The advantage was particularly evident in cognitive learning outcomes and in the fluency and elaboration indicators, while the improvement in originality was nearly equivalent between the two groups. These findings suggest that the integration of projects, STEM, and AI has the potential to create a more active, collaborative, contextual, and higher-order-thinking-oriented learning environment.

IV. CONCLUSION

Based on the findings, the implementation of Artificial Intelligence (AI)-assisted, *Science, Technology, Engineering, and Mathematics* (STEM)-based Project-Based Learning (PjBL) had a significant effect on the cognitive learning outcomes and creative thinking skills of seventh-grade students learning about interactions among living organisms at SMPN 1 Samarinda. The experimental class demonstrated greater improvement in cognitive learning outcomes than the control class, with a mean N-Gain of 0.83, categorized as high, compared with 0.58 in the control class, categorized as moderate. For creative thinking skills, the experimental class also demonstrated greater improvement, with a mean N-Gain of 0.68 compared with 0.57 in the control class, although both were categorized as moderate. The improvement in the experimental class was particularly evident in the *fluency* and *elaboration* indicators, whereas improvement in *originality* was relatively comparable between the two classes. These findings suggest that the integration of PjBL, STEM, and AI has the potential to support more active, contextual, collaborative learning while fostering students' higher-order thinking skills.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

AUTHOR CONTRIBUTIONS

***Kasfa Atharisna:** Conceptualization, Investigation, Data Collection, Formal Analysis, Writing – Original Draft, and Visualization. **Jailani:** Conceptualization, Methodology, Validation, Supervision, and Writing – Review & Editing. **Herliani:** Methodology, Validation, Supervision, and Writing – Review & Editing. **Suparno Putera:** Validation, Supervision, and Writing – Review & Editing. All authors contributed to the interpretation of the findings, critically reviewed the manuscript, and approved the final version for publication.*

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DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES

During the preparation of this manuscript, the authors used generative AI and AI-assisted technologies to support language editing, proofreading, and improvements in the clarity and readability of the manuscript. These technologies were not used to generate research data, conduct statistical analyses, or determine the findings and conclusions of the study. All AI-assisted outputs were critically reviewed, revised, and verified by the authors. The authors take full responsibility for the accuracy, integrity, and content of the final manuscript.

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