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Integration of Project-Based Learning-STEM and Computational Thinking to Improve Students Scientific Creativity

Faradina*[1], Ashari A. Usman[2], Sumarni Sahdjat[3], Fitri Ayu Lestari[4]
[1,4] Pendidikan Ilmu Pengetahua Alam, Universitas Nahdlatul Ulama Maluku Utara, Indonesia;
[2] Pendidikan Fisika, Institut Sains dan Kependidikan Kie Raha Maluku Utara, Indonesia;
[3]Pendidikan Fisika, Universitas Khairun, Ternate, Indonesia.

Email: faradinaunutara@gmail.com, asyharifisika@gmail.com, sumarni_sahjat@yahoo.com , fitriayulestarii888@gmail.com

Abstract

Scientific creativity is one of the most essential aspects of 21st-century skills emphasized in science learning, as it enables students to generate scientific ideas that are original, flexible, and applicable in solving contextual problems. Therefore, this study aims to describe the implementation of Project-Based Learning (PjBL) integrated with STEM and Computational Thinking to enhance students' scientific creativity.This study employed a quantitative approach with a pre-experimental method using a one-group pretest–posttest design. The sample consisted of 29 students from Class VIII-A at SMP Negeri 3 Ternate City. The research instruments included a scientific creativity test and an observation sheet to assess the implementation of the learning process. Data were analyzed using a paired sample t-test and N-Gain calculation to determine the improvement in students' scientific creativity.The results showed that the implementation of the learning process reached 85%, which falls into the good category. In addition, the paired sample t-test results indicated a significance value of 0.000 < 0.05, demonstrating a significant difference between pretest and posttest scores. The average N-Gain score was 0.61, which is categorized as moderate. In conclusion, the implementation of Project-Based Learning (PjBL) integrated with STEM and Computational Thinking is associated with improvement of students' scientific creativity.

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INTRODUCTION

The development of science and technology in the 21st century, marked by the Industrial Revolution 4.0 and the transition toward Society 5.0, has brought significant changes to education, particularly in the competencies that students are expected to possess. Modern education systems no longer focus solely on the mastery of concepts but also emphasize the development of higher-order thinking skills such as creativity, critical thinking, problem-solving, and collaboration. In the context of science learning, the mastery of these skills is crucial, as learning is not only directed toward understanding natural phenomena but also toward students' ability to generate innovative solutions (Suryani et al., 2024). Global education reports highlight that creativity and problem-solving abilities are key indicators of essential competencies that must be developed in contemporary education systems (OECD, 2023). Scientific creativity is defined as the ability to generate scientific ideas that are original, flexible, and applicable (Ajwar et al., 2021; Wijayanti et al., 2025).

Scientific creativity plays an important role in improving the quality of science learning, as it encourages students to think openly, exploratively, and innovatively. Students with strong scientific creativity are capable of generating multiple alternative solutions to scientific problems. Furthermore, creativity enables students to connect various concepts, leading to deeper understanding. Research indicates that creativity-based learning can enhance motivation, student engagement, and problem-solving skills (Shiyu, 2024). However, classroom practices still show that science learning is often dominated by conventional, teacher-centered approaches. The learning process tends to emphasize memorization rather than exploration and scientific investigation. As a result, students have limited opportunities to develop ideas, conduct experiments, and produce creative solutions. Consequently, students' scientific creativity remains low, indicating the need for more active and contextual learning innovations.

One effective learning model for fostering creativity is Project-Based Learning (PjBL). This model emphasizes learning through project activities that actively involve students in investigation, solution design, and the creation of tangible products as learning outcomes. Through PjBL, students are not merely recipients of information but become central actors in the learning process, enabling them to develop creative thinking and problem-solving skills optimally. Research shows that the implementation of PjBL can increase student engagement and promote creativity and innovation in learning (Wicaksono et al., 2024; Cahyani, 2021). In addition, PjBL provides authentic learning experiences, as students are confronted with real-life problems, making learning more meaningful.

The effectiveness of PjBL is further enhanced when integrated with the STEM (Science, Technology, Engineering, and Mathematics) approach. STEM emphasizes the integration of multiple disciplines in solving real-world problems in an interdisciplinary manner. STEM learning provides students with opportunities to develop analytical thinking, creativity, and engineering design skills through exploration, experimentation, and innovation. Various studies have shown that project-based STEM learning significantly improves creative thinking and problem-solving skills (Thibaut et al., 2020; Hsu et al., 2021). Preparing students for future success encourages them to become problem solvers, innovators, inventors, and logical thinkers, which are supported by STEM education (Postiomitou, 2023). STEM learning offers opportunities for students to enhance analytical thinking, creativity, and engineering design skills. Research also confirms that project-based STEM significantly improves creative thinking and problem-solving abilities (Hang, 2024; Sirajudin et al., 2021).

In addition to the STEM approach, strengthening students' thinking skills in science learning can also be achieved through the implementation of Computational Thinking (CT). Computational Thinking is a systematic thinking approach that includes decomposition, pattern recognition, abstraction, and algorithm design (Srisangngam & Dechsura, 2020; Mendrofa, 2024). Through this approach, students are trained to analyze problems in a structured and logical manner. It involves several key stages, including breaking down problems into simpler components, identifying patterns and relationships among elements, abstracting relevant information, and designing logical procedures in the form of algorithmic steps (Bazhenova et al., 2024). These components help students analyze problems systematically and critically. Therefore, Computational Thinking plays a crucial role in helping students develop structured thinking in analyzing and solving complex problems.

The integration of Computational Thinking in science learning is increasingly relevant to the demands of the 21st century, which emphasize complex problem-solving skills. Various studies indicate that the application of Computational Thinking in science learning not only enhances logical thinking but also fosters students' creativity in designing innovative solutions (Amrizaldi, 2025; Le et al., 2020). Through activities such as problem modeling, pattern analysis, and algorithm-based solution design, students can develop reflective and innovative thinking. Furthermore, integrating Computational Thinking helps students understand the relationship between scientific concepts and technological applications in everyday life (Putri et al., 2024). This makes learning more meaningful and contextual while supporting the development of higher-order thinking skills. Thus, the implementation of Computational Thinking in science learning can serve as an effective strategy to improve the quality of the learning process and prepare students to face the increasingly complex challenges of the digital era (Nurazizah et al., 2025). Moreover, this integration encourages students to connect conceptual knowledge with practical activities, making learning experiences more relevant to daily life (Yogyanto et al., 2024).

Previous studies have shown that PjBL can enhance students' learning motivation and critical thinking skills due to its focus on active engagement and problem-solving (Rodiah & Dani., 2025). Meanwhile, the STEM approach has been proven to improve creativity through design activities and scientific experimentation (Tran et al., 2021). On the other hand, Computational Thinking helps students understand problems systematically through decomposition and pattern recognition, enabling them to produce more innovative and logical solutions (Zhang et al., 2025). Therefore, the integration of these three approaches represents a relevant strategy for developing 21st-century skills, particularly in enhancing students' scientific creativity.

Although numerous studies have examined the implementation of PjBL, STEM, and Computational Thinking in science learning, most of them have addressed these approaches separately. Research that integrates all three approaches simultaneously remains limited, particularly in efforts to improve students' scientific creativity. This indicates a research gap that needs further exploration to develop more comprehensive learning strategies.

Based on the above discussion, the integration of Project-Based Learning with STEM and Computational Thinking is considered a promising strategy for enhancing students' scientific creativity. Project-based learning provides opportunities for students to explore ideas, design solutions, and produce innovative products. When combined with STEM and Computational Thinking, students not only develop creativity but also enhance their analytical and systematic thinking skills. Therefore, this study aims to describe the implementation of Project-Based Learning integrated with STEM and Computational Thinking to improve students' scientific creativity. This research is expected to contribute to the development of innovative learning models that support 21st-century skills in science education.

RESEARCH METHODS

The method used in this study was a quantitative research approach with a pre-experimental design. The research design employed was a one-group pretest–posttest design, which involves a single experimental class without a control group. In this design, students are given a pretest, followed by treatment, and concluded with a posttest (Aini et al., 2025; Suryatama et al., 2024). This design was used to determine changes in students' abilities before and after the implementation of Project-Based Learning integrated with STEM and Computational Thinking approaches.

The study was conducted at SMP Negeri 3 Ternate City during the second semester of the 2025/2026 academic year. The sampling technique used was purposive sampling, based on the consideration that the selected class had heterogeneous academic abilities and had studied material relevant to the research topic. The selected sample was Class VIII-A, consisting of 29 students. The research instruments included a written test to measure scientific creativity and an observation sheet to assess the implementation of the learning process. The indicators of scientific creativity used in this study included fluency, flexibility, originality, and elaboration.

Data collection was carried out in two stages, namely tests and observations. The tests were administered twice, namely a pretest before the learning process to determine the students' initial scientific creativity ability and a posttest after the learning process to measure the improvement after being given the treatment. The research instrument in this study was a scientific creativity test developed based on indicators of scientific creativity, namely fluency, flexibility, originality, and elaboration, and students' answers were assessed using a scientific creativity assessment rubric. The instrument that was developed then underwent a trial phase, which included content validity, construct validity, and reliability testing. Content validity testing was conducted through expert validation by science education experts to assess the suitability of the content, construct, and language of the instrument, and the results showed a high level of validity. Next, the instrument was tested on students, and the results of the item-total correlation analysis showed that all the test items were declared valid. The reliability test of the instrument was carried out using Cronbach's alpha coefficient, where the instrument is declared reliable if the Cronbach's alpha value > 0.60. The reliability test results showed that the instrument has a high level of reliability, making it suitable for use in this study. In addition, observations were conducted during the learning process to obtain information about the implementation of Project-Based Learning integrated with STEM and Computational Thinking.

The collected data were analyzed using descriptive statistical analysis to determine the mean scores of students' scientific creativity, and inferential statistical analysis to examine significant differences between pretest and posttest scores using a paired sample t-test. Furthermore, the improvement in students' scientific creativity was analyzed using the N-Gain calculation to determine the level of improvement after the treatment. The N-Gain was calculated using the following formula:

$$g = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}} \qquad 1)$$

Where g is Normalized Gain (N-Gain), S_{post} is Students' posttest scores, S_{pre} is Students' pretest scores and S_{max} is ihe maximum score that can be achieved (ideal). The N-Gain values are classified into three categories: high (g > 0.70), medium (0.30 ≤ g ≤ 0.70), and low (g < 0.30). These categories are used to determine the effectiveness level of the learning process in improving students' scientific creativity (Sudjana, 2005; Hake, 1999).

RESULTS AND DISCUSSION

The implementation of Project-Based Learning integrated with STEM and Computational Thinking was carried out in accordance with the planned instructional design and was observed by an observer evaluating the teacher's performance during the learning process. Throughout the learning activities, the teacher acted as a facilitator, guiding students through discussions, observations, and contextual problem-solving activities. Students were presented with a problem scenario involving the installation of an inclined plane in the school warehouse to assist staff in moving heavy objects more easily. This problem served as a context for understanding how effort can be minimized by applying the principles of simple machines. The teacher then posed the question, *"How can we design an inclined plane that enables the efficient movement of objects with minimal effort?"* The teacher provided criteria for success as well as constraints that had to be met in designing the proposed solution, enabling students to draw conclusions based on the results of their experiments. The criteria and constraints provided to the students are presented in the following table.

Table 1. Criteria for a Successful Solution and Constraints

Criteria for a Successful Solution	Constraints
The designed tool is able to move objects from one place to another more efficiently.	Each group uses the same mass of objects and the same size of the inclined plane.
The tool is simple in design and can be constructed using easily accessible materials	Each group is given the same amount of time for experimentation and observation.
The experiment can be measured and analyzed by students to obtain valid results.	Distance and force measurements are conducted using the same measuring instruments.

To determine whether the implementation of Project-Based Learning integrated with STEM and Computational Thinking was carried out effectively, the researcher used an observation sheet as the instrument to assess the implementation of the learning process. This instrument was used to observe each stage of the learning activities conducted in the classroom. The results of the observation of the implementation of Project-Based Learning integrated with STEM and Computational Thinking are presented in Table 2.

Table 2. Observation Results of Learning Implementation

Activity	Score	Description
Activity Introduction/ Opening	13	The lesson began with a systematic opening conducted by the teacher. The teacher first organized the classroom atmosphere, checked students' attendance, and ensured that learning resources and media were well prepared. The teacher then provided motivation to enhance students' readiness to participate in the learning process. An apperception activity was carried out by asking questions related to the material from the previous meeting. In addition, the teacher conveyed the learning objectives to be

Activity	Score	Description
		achieved and clearly explained the sequence of learning activities to the students.
Core Activities	19	The teacher initiated the core activities by explaining the concepts of work and energy as a foundation for students to understand the problem to be solved through project-based learning. Students were then divided into groups and guided to discuss solutions to problems related to the application of an inclined plane for moving objects more efficiently. The teacher distributed student worksheets (LKPD) containing project instructions and experimental procedures. Each group prepared the required tools and materials, such as an inclined plane, test objects, and measuring instruments. Students conducted observations of object motion on inclined planes with varying angles. The results were recorded systematically in the worksheets provided. Students then discussed the results to analyze the relationship between force, work, and energy. This process also involved computational thinking skills, such as identifying problems, organizing experimental data, and analyzing patterns among variables. Within the context of Project-Based Learning integrated with STEM, students not only understood scientific concepts but also applied engineering and technological principles to design solutions. Finally, each group concluded their findings and presented the results as part of the project evaluation process.
Closing	14	The teacher guided each group to present the results of their projects. Students presented their observations and conclusions from the inclined plane experiment. The teacher then facilitated a class discussion to examine the relationship between force, work, and energy based on the collected data. The discussion results were recorded by students as a summary in the provided worksheets. The teacher also encouraged students to reflect on the learning process, including the problem-solving steps used during the project. Students were asked to identify key concepts learned. The teacher provided reinforcement of the concepts of work and energy and connected them to real-life applications. Finally, the teacher summarized the lesson, provided feedback on students' work, and informed them about the next learning activities.
Total Score	46	
Maximum Score	54	
Percentage	85%	Good

Based on the table presented, the teacher has implemented the learning process effectively. This is indicated by the percentage of learning implementation, which reached 85% and falls into the good category. The implementation of the learning activities in the introduction, core, and closing stages demonstrates that the teacher was able to manage the learning process systematically, apply the STEM-based Project-Based Learning (PjBL) model, and actively engage students in the learning activities.

Description of Students' Scientific Creativity Score Data

Descriptive analysis of the improvement in students' scientific creativity skills was conducted based on pretest and posttest scores obtained before and after the implementation of Project-Based Learning integrated with STEM and Computational Thinking. This analysis aimed to determine the maximum score, minimum score, mean, range, and score variation, as presented in Table 3 below.

Table 3. Descriptive Statistics of Students' Scientific Creativity (Pretest and Posttest)

	N	Range	Minimum	Maximum	Mean	St. Deviation	Variance
Pretest	29	38.67	43.33	82.00	58.62	9.21	84.83
Posttest	29	25.24	71.43	96.67	84.17	7.84	61.46
Valid N (listwise)	29						

Based on Table 3, the quantitative descriptive analysis shows that the pretest scores of 29 students had a range of 38.67, with a minimum score of 43.33, a maximum score of 82.00, and a mean of 58.62. The standard deviation of 9.21 indicates that the distribution of pretest scores was relatively wide, while the variance of 84.83 reflects considerable variation in students' initial abilities. In the posttest, the minimum score increased to 71.43 and the maximum score to 96.67, with a range of 25.24 and a mean of 84.17. The standard deviation decreased to 7.84, indicating that the distribution of scores after the learning process was more homogeneous compared to the pretest. These results indicate an overall improvement in students' scientific creativity after the implementation of Project-Based Learning integrated with STEM and Computational Thinking. Furthermore, the pretest and posttest data were tested for normality using the SPSS version 25 program, with the results presented as follows.

Table 4. Results of the Normality Test

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	133	29	.189	.954	29	.217
Posttest	206	29	.062	.941	29	.096

Based on Table 4, the Kolmogorov–Smirnov and Shapiro–Wilk tests indicate that all significance values exceed 0.05 (pretest: 0.189 and 0.217; posttest: 0.062 and 0.096), confirming that the data are normally distributed. Accordingly, a paired sample t-test was conducted using SPSS version 25 to examine differences between the mean pretest and posttest scores, with the results presented as follows.

Table 5. Paired Sample t-test Results

		Paired differences					t	df	Sig.(2-tailed)
		Mean	StD	SEM	95% CID				
					Lower	Upper			
Pair 1	Pretest-Posttest	-25.55	10.50	1.95	-29.54	-21.56	-13.10	28	.000

StD: Std. Deviation, SEM: Std Error Mean, CID: confidence interval of the difference

Based on Table 5, the significance value (Sig. 2-tailed) is 0.000, which is lower than 0.05, indicating a statistically significant difference between the pretest and posttest scores of students' scientific creativity. This finding demonstrates that the implementation of Project-Based Learning integrated with STEM and Computational Thinking has a significant effect on improving students' scientific creativity.

Scientific Creativity Improvement (N-Gain)

To determine the extent of improvement in students' scientific creativity after the intervention, the N-Gain score was used. The calculation of the N-Gain score for students' scientific creativity is presented as follows.

$$\langle g \rangle = \frac{84{,}17 - 58{,}62}{100 - 58{,}62} = \frac{25{,}55}{41{,}38} = 0{,}61$$

Based on the calculation, the N-Gain value of 0.61 indicates a moderate level of improvement in students' scientific creativity. This finding suggests that the implementation of Project-Based Learning integrated with STEM and Computational Thinking is effective in enhancing the scientific creativity of Class VIII-A students at SMP Negeri 3 Ternate City. The detailed N-Gain results based on pretest and posttest scores are presented in Table 6.

Table 6. N-Gain Calculation Results of Students' Scientific Creativity

	Rata-rata	N-Gain	Kategori
Pretest	58.62	0.61	Sedang
Posttest	84.17		

Based on Table 2, the improvement in students' scientific creativity falls into the moderate category, indicating that the implemented learning approach is sufficiently effective in enhancing students' scientific creativity.

Based on the findings, the implementation of Project-Based Learning (PjBL) integrated with STEM was carried out effectively, as indicated by the learning implementation rate of 85%, which falls into the *good* category. This result suggests that the teacher successfully managed the learning process in a systematic manner, following the PjBL syntax from presenting contextual problems to evaluating project outcomes. Despite this positive implementation, several challenges were identified, particularly in the development of students' scientific creativity. Some students experienced difficulties in generating original and innovative ideas when designing solutions to the given problem. This was evident in the inclined plane designs, which tended to be similar across groups, indicating that the originality aspect of scientific creativity had not been fully developed.

In addition, students showed limited flexibility in thinking, especially in connecting the concepts of work, force, and energy with their designs. While some students were able to construct functional tools, they did not fully consider efficiency from a scientific perspective. This suggests that the elaboration and flexibility dimensions of scientific creativity still require further development. As noted by Rey & Calonge (2022), scientific creativity involves not only generating ideas but also refining and adapting them scientifically. Therefore, more structured scaffolding from the teacher is needed to support deeper idea development.

Another challenge emerged during the reflection and evaluation stages, where some students were unable to identify the strengths and weaknesses of their products. This indicates that the evaluative dimension of scientific creativity remains underdeveloped. Furthermore, time constraints limited the iterative design process. Several groups conducted only a single trial without revising their designs, reducing opportunities to produce more innovative solutions. In fact, iterative processes are essential in fostering scientific creativity, as they enable continuous refinement of ideas (Henriksen & Mishra, 2023).

Despite these limitations, the results demonstrate a significant improvement in students' scientific creativity. The mean score increased from 58.62 in the pretest to 84.17 in the posttest. Additionally, the paired sample t-test revealed a significance value of 0.000 ($p < 0.05$), indicating a statistically significant difference between students' initial and final abilities. The N-Gain value of 0.61, categorized as moderate, further confirms that the implemented learning approach was sufficiently effective in enhancing students' scientific creativity. These findings suggest that project-based learning integrated with STEM provides meaningful learning experiences that foster creativity development.

This finding is consistent with previous studies indicating that project-based learning enhances scientific creativity through active engagement in investigation and problem-solving (Krajcik & Shin, 2022). Moreover, STEM integration has been shown to promote creative and innovative thinking through interdisciplinary approaches (Li et al., 2023). Other studies also highlight that contextual project-based learning improves students' ability to generate original and applicable scientific ideas (Cheng et al., 2022).

Furthermore, the integration of PjBL and STEM encourages higher-order thinking. Students are not only engaged in conceptual understanding but also in applying knowledge to real-world situations. This is reflected in their ability to design inclined planes as practical solutions. The process involves key components of scientific creativity, including fluency, flexibility, originality, and elaboration. These components are widely recognized as core indicators of scientific creativity (Said-Metwaly et al., 2023).

In addition, this learning approach provides contextual and meaningful learning experiences. Through project activities, students connect scientific concepts with real-life applications, making learning more relevant. This aligns with research suggesting that STEM-based learning enhances the connection between theory and practice, leading to deeper understanding (Nguyen et al., 2022). Collaborative activities also allow students to exchange ideas and co-construct solutions, further enriching their creative thinking processes. Overall, the findings indicate that students' scientific creativity can be effectively developed through active, contextual, and project-based learning environments. The observed improvement confirms that scientific creativity is not a fixed ability but can be enhanced through appropriate learning experiences. This is supported by research showing that exploratory and experimental learning environments significantly foster student creativity (Zhang et al., 2024).

In conclusion, the integration of Project-Based Learning with STEM makes a significant contribution to improving students' scientific creativity. This approach not only enhances learning outcomes quantitatively but also develops essential creative thinking skills required in the 21st century. Therefore, its implementation should be further expanded and optimized in science education. As a follow-up, teachers need to provide more intensive guidance in supporting students' creative idea development, particularly during reflection and evaluation stages. Additionally, better time management is required to ensure that all phases of PjBL, especially iterative design processes, can be implemented optimally. Future research is recommended to develop more varied instructional designs and employ more comprehensive assessment instruments to measure students' scientific creativity in greater depth.

CONCLUSION

Based on the results and discussion, it can be concluded that the implementation of Project-Based Learning (PjBL) integrated with STEM and Computational Thinking is related to the improvement of students' scientific creativity in Grade VIII at SMP Negeri 3 Ternate, as indicated by a significance value of $0.000 < 0.05$, as well as an increase in the average score from 58.62 in the pretest to 84.17 in the posttest, with an N-Gain value of 0.61 categorized as moderate. This improvement occurred through active student involvement in each stage of project-based learning, particularly in problem identification, solution design, experimentation, and collaborative evaluation of project results in a contextual learning environment. The integration of STEM and Computational Thinking contributes to the development of students' scientific creativity by encouraging systematic, analytical, and innovative thinking processes, including problem decomposition, pattern recognition, and designing solutions based on science. However, some aspects of scientific creativity, such as originality, flexibility, and evaluative skills, still require further improvement through more structured mentoring and a stronger emphasis on the reflection and evaluation stages. Based on these findings, it is recommended that teachers implement PjBL integrated with STEM and Computational Thinking as an alternative learning strategy to support the development of higher-order thinking skills. It is expected that schools support the implementation of innovative learning by providing adequate facilities and sufficient time for project-based activities, and future research is recommended to use a stricter research design and develop more comprehensive instruments to measure students' scientific creativity more deeply.

AUTHOR CONTRIBUTIONS

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This section describes the roles of each researcher in conducting the study and preparing the scientific article. Faradina, as the principal investigator, was responsible for research design, instrument development, data analysis, and manuscript writing. Asyhari contributed to data collection and the implementation of the study in the field. Fazrul was involved in data analysis and manuscript revision. Sumarni contributed to instrument validation, interpretation of the findings, and refinement of the discussion. Fitri Ayu Lestari was responsible for data processing, preparation of the research report, and final editing of the manuscript prior to publication.

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